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**POWDERED AND PELLETED (GRANULAR) COMPOST AS AN ALTERNATIVE CARRIER FOR RHIZOBIAL INOCULANTS**

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**Project Title: Powdered and Pelleted (Granular) Compost as an Alternative Carrier for Rhizobial Inoculants**

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## (a) Abstract/Summary

Six composts were compared to inoculant quality peat for physical, chemical, microbiological and phytotoxic characteristics. Three composts were developed into powdered seed-applied and granular rhizobial inoculants for pea and lentil and evaluated for viability and nodulation ability after storage and effectiveness in inducing symbiotic nitrogen fixation in growth chamber and field experiments. All but one of the composts exhibited characteristics generally similar to peat. Sterilization with gamma radiation prior to inoculation improved long-term storage. Growth chamber experiments under near-sterile conditions indicated the composts performed nearly as well as commercial control products. Field trials were inconclusive because of drought, but indicated potential for further development.

## (b) Executive Summary

In Canada, ground peat is the carrier most commonly used in conventional legume inoculant production. However, inoculant-quality peat can be difficult, or expensive, to obtain and at best can be considered only a very slowly renewable resource – one that is currently being mined at a rate faster than it is being regenerated in active bogs. In addition, the cost of producing compost is approximately one-tenth the cost of mining an equivalent amount of inoculant quality peat – a cost that can be passed on to the producer.

The study reported on here examines the feasibility of developing compost into an inoculant product for pulse crop production. Both powdered seed-applied and granular products were developed and evaluated. The study represents the first stages in evaluating composts and identifies several areas where more development is needed.

The objectives of the study are to:

(i) Assess the use of various compost types as carriers for *Rhizobium* inoculants;

(ii) Determine the feasibility of preparing pelletized (granular) compost based inoculants;

(iii) Compare nodulation, $N_2$ fixation and yield of crops inoculated with pelleted or seed-coated compost-based inoculants.

Composts from six sources were compared to inoculant quality peat for a wide variety of physical, chemical and microbiological properties using standards developed by the Canadian government. Only one property, fairly high amounts of salts, was identified as being a potential concern among several of the composts. Salts are present in fairly high amounts in animal urine and feces and reflect the fact that livestock manures and bedding were the source materials composted. One of the composts contained high levels of certain bacteria. This compost was produced using a different system for composting than all of the other samples and does not represent a typical compost available in Saskatchewan or anywhere else in Canada. Two different batches of three of the composts were obtained at different times (approximately 15 months apart). When the batches were compared there was little difference between them in the physical and chemical properties tested. This indicates a relatively consistent product from the compost producers.

Three of the original six composts were selected for further studies. Powdered and granulated products were produced and commercial strains of *Rhizobium leguminosarum* (the bacteria that causes pea and lentil to fix nitrogen from the atmosphere) were applied to the products. Both non-sterile and sterilized composts were tested. One important feature of commercial inoculants is that they can be stored in dry, cool conditions for 6-9 months before being used. When the composts were sterilized before the *Rhizobium* was applied, they were able to support high numbers the rhizobia for a 225 day storage period. Sterilization killed most of the native bacteria that compete with the applied rhizobia and reduce their effectiveness. The composts were not quite as good as the commercial inoculant products that they were compared to. Over the 225 day storage period small numbers of rhizobia on the composts died, whereas the numbers of rhizobia on the commercial peat-based and granular products were very stable. This is probably due to higher water contents in the composts and is an area for further investigation.

Storage of the inoculants also reduced the ability of the inoculants to nodulate pea plants and induce nitrogen fixation compared to inoculants that were freshly prepared. However, the same thing was observed for the commercial products that we tested. Clearly, there is a finite shelf-life for any of the inoculants.

Growth chamber studies performed in low nitrogen soil obtained from a producer's field indicated that overall, the compost inoculants (both powdered seed-applied and granular) were as good as the commercial inoculants in the pea experiments. None of the compost-based inoculants was better than any of the others, indicating that the composts represented a fairly consistent product. There were problems in the lentil experiment. Two of the

compost-based inoculants failed completely, in that no nodules developed on the plants, growth was stunted and nitrogen fixation was minimal.

Unfortunately, because of the drought experienced in 2001 and 2002, field trials are inconclusive. Under drought conditions, the compost–based inoculants performed generally as well as the commercial inoculants, although growth and nitrogen fixation at all of the sites was poor.

Overall, this initial series of experiments indicates that there is good potential for developing composts into commercial inoculant products. There is clearly more work to be done in developing the composts into a high quality, reliable inoculant for pulse crops.

## (c) Technical Report

### 1.0 Introduction:

Inoculation of legume seeds with *Rhizobium* or *Bradyrhizobium* is a common practice in agriculture. In Canada, ground peat is the carrier most commonly used in conventional legume inoculant production. However, inoculant-quality peat can be difficult, or expensive, to obtain (Brockwell, 1985). Though historically this has not been the case in Canada, heightened environmental awareness and concern over the effects of peat land development on the conservation and protection of wetland wildlife habitats, the protection of rare or unusual species, the release of carbon gases and its relationship to global warming, and water quality issues have resulted in rising costs and concerns within the inoculant industry over the future availability of inoculant-quality peat. In addition, peat can (at best) be considered only a very slowly renewable resource – one that is currently being mined at a rate faster than it is being regenerated in active bogs. These factors, together with general concerns over environmental quality and the sustainable use of our natural resources have led to renewed interest in the development of new and creative inoculant formulations. The development of pelleted (granular) compost-based inoculants represents one such innovation.

Compost, like peat, is essentially a humus-rich organic soil which provides and excellent medium for sustaining large microbial populations. Both compost and peat possess numerous properties beneficial for microorganisms; high water holding capacity and water retention; high buffer capacity and cation exchange capacity, nearly neutral pH and relatively high levels of available nutrients (Nethery, 1991; Haug, 1993). In addition, both compost and peat are nontoxic, biodegradable and non-polluting. Compost is available at a substantially lower cost than that of peat; i.e., compost is generally available at a cost of $20-$40 per tonne compared to peat which has an average cost of $200-$250 per tonne. The overall objective of this study was to determine the feasibility of using compost as a carrier for rhizobial inoculants.

The objectives of this project are to:

(iv) Assess the use of various compost types as carriers for *Rhizobium* inoculants;

(v) Determine the feasibility of preparing pelletized (granular) compost based inoculants;

(vi) Compare nodulation, $N_2$ fixation and yield of crops inoculated with pelleted or seed-coated compost-based inoculants.

**2.0 Methods:**

**2.1 Compost sources:**

Compost samples were obtained from five commercial distributors and one government institution in western Canada (Table 2.1). In addition, inoculant quality peat samples were obtained from two manufacturers of rhizobial inoculants commonly used in Saskatchewan and on the Canadian prairies (Table 2.1). All of the composts except the RSC composts contained primarily animal wastes and bedding and were composted using windrow operations. Source materials for the RSC composts consisted of human food wastes mixed with a high-carbon bulking agent and were composted using an in-vessel composter followed by curing in a windrow.

***Table 2.1. Source and description of the peat and compost samples.***

| Supplier | ID Code | Description |
|---|---|---|
| MicroBioRhizoGen Corp.[1]; Saskatoon, SK | MBR-r | Inoculant quality peat (raw, non-sterile). |
| | MBR-s | Inoculant quality peat (sterile). |
| LiphaTech; Milwaukee, WI | LT-1 | Inoculant quality peat (raw, non-sterile). |
| Duncan Farms, Ltd.; Langley, BC | BC-1 | Composted swine manure mixed with bedding material (i.e., saw dust). Pig-on-litter production system. |
| Corcan Agribusiness; Prince Albert, SK | PA-1 | Composted cattle manure mixed with straw. |
| EcoAg Initiatives; Calgary, AB | EA-1 | Granular horticultural grade compost from cattle manure & animal bedding. |
| | EA-2p | Pelleted horticultural grade compost. |
| Forestry Farm Park Saskatoon Zoo; Saskatoon, SK | SZ-1 | Composted animal waste and bedding material mixed with horticultural waste, grass clippings and leaves. |
| Moose Jaw Exhibition Co., Ltd; Moose Jaw, SK | ME-1 | Composted residential yard waste (mostly grass clippings and leaves) mixed with barn waste (mostly horse bedding). |
| Saskatoon Regional Psychiatric Centre; Saskatoon, SK | RSC-1 | Composted food waste mixed with shredded paper, grass clippings and wood chips. In-vessel composting followed by 1-year of curing in a windrow. |
| | RSC-1e | Compost treated with *Envirozyme* to accelerate composting. In-vessel composting – only about six weeks of curing in a windrow. |

[1]MicroBioRhizogen Corporation is now Becker Underwood, Ltd.

**2.2 Chemical & physical characterization:**

Composts were characterized according to the methods established by the U.S. Composting Council (Leege & Thompson, 1997). Characterizations include: pH, EC, and trace element (As, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Se, Zn) concentrations, total organic-C, total N, and total S; C:N, C:S, and N:S ratios; total solids, ash, and biodegradable volatile solids content; and water holding capacity. For comparative purposes, both the MBR and LT peat samples were included in this analysis.

During the course of the study, three of the original six composts (EA-1, PA-1, and SZ-1) were selected for intensive evaluation as carriers for *Rhizobium*. Larger quantities (identified as Batch 2) of the selected inoculants (EZ, PA and SZ) were obtained and subjected to the same physical and chemical characterization. The SZ-1 was eventually eliminated because of problems with handling the product.

**2.3 Microbial characterization:**

Indigenous microbial populations in the peat and composts were determined following the methods outlined in *Test Methods for the Examination of Composting and Compost* – prepared by the U.S. Composting Council (Leege & Thompson, 1997). In general, each sample (peat and compost) was tested for the presence of total heterotrophs, including human and phyto-pathogenic bacteria (Nelson & Child, 1981; Dunfield et al., 1996; Leege & Thompson, 1997). Assessment of human pathogenic bacteria (*Enterobacteriaceae*, *Klebsiellae* and fecal coliforms) was performed using selective culture media. Fresh compost samples (10 g) were suspended in $H_2O$ and then serially diluted (1/10). Aliquots of appropriate dilutions were plated onto the following culture media: (*i*) MacConkey's Agar – enumeration of presumptive *Enterobacteriaceae*; (*ii*) MacConkey's plus inositol and carbenicillin – to separate presumptive *Enterobacteriaceae* and non-*Enterobacteriaceae*; (*iii*) Actinomycete Isolation Agar – total actinomycete populations; (*iv*) Czapec-Dox Agar – for total fungi; and, (*v*) Trypticase soy agar – for total heterotroph bacteria counts (Bagley & Seidler, 1978; Foster & Rovira, 1975). Inoculated plates (n = 4) were incubated at 28°C and 37°C for heterotrophs and *Enterobacteriaceae*, respectively; bacterial colony-forming units (cfu) were enumerated after 72 to 120 h. A random number table was consulted and 50 colonies from a plate were isolated. Bacteria were streaked on original isolation medium, incubated for 48 h at 28°C, checked for purity and stored refrigerated until whole-cell fatty acid methyl ester (FAME) analyses could be run. FAME profiles are used to identify bacteria.

Fecal coliforms were used as indicator organisms for the presence of human enteropathogens using the Most Probable Number (MPN) assay to determine the total coliform and fecal coliform populations in compost samples. For fecal coliforms, a 1.0 mL aliquot of each of five dilutions was placed into five replicate test tubes containing an inverted DURUM tube in each and either, ECM (EC medium) or LTB (Lauryl Tryptose Broth) media. Tubes corresponding to ECM were incubated at 35°C for 3 hours then transferred to 44.5°C for 21 hours. Tubes corresponding to LTB - were incubated at 35°C for 24 hours. All presumptive pathogenic bacteria were identified FAME profiles following the procedures described by MIDI (1991).

**2.4 Phytotoxicity (Seed Germination & Root Elongation):**

**2.4.1 Cress phytotoxicity bioassay (Zucconi et al., 1981a, b; Leege & Thompson, 1997):**

Because of its high sensitivity to phytotoxins, garden cress (*Lepidium sativum*) is an ideal plant for assessing the ecotoxicity of low-level toxins. In general, the test consists of (i) obtaining an aqueous extract from each compost; (ii) incubating cress seeds in contact with the compost:water extracts; and (iii) determining seed germination and root elongation.

A sub-sample of each compost was mixed with deionized water (50 mL type II DI water per 40 g moist compost); incubated at room temperature (ca. 22°C) for 30 minutes; filtered through cheesecloth and centrifuged for 15 min at 8000 *g* and 4°C; and filter-sterilized through a 0.45-μm membrane filter (Gelman Scientific, Ann Arbor, MI). While maintaining aseptic conditions, a dilution series was prepared (undiluted, 1:2 extract:water, and 1:4 extract:water) from each extract (i.e., for each compost). One milliliter of extract was pipetted into a 50-mm sterile Petri dish lined with filter paper (Whatman No. 1; 4.25 cm diameter) and 25 cress seeds placed in each dish. Seeds were soaked for 1 h in sterile deionized water before exposure to the extracts. Each dilution was replicated 10 times and the Petri dishes incubated for 24 h at 27°C in the dark. Seed germination was stopped by adding 1-mL 50% (v/v) ethanol to each dish. Treatments were evaluated by determining the number of germinated seeds and the length of the radicle.

Percent relative germination (PRG) was calculated by dividing the mean germination of each treatment (MGT) by the mean germination in the control (water) extract (MGC) and multiplying this number by 100. The percent relative root length (PRRL) was calculated by dividing the mean radicle length of each treatment (MRLT) by the mean radicle length of the control (MRLC) and multiplying this number by 100. The phytotoxicity of the compost extracts was assessed using Zucconi's germination index (GI), which was calculated by multiplying the relative germination by the relative root length (Table 2.2).

*Table 2.2 Garden cress germination index description.*

| Germination Index | Rating (Description) |
|---|---|
| 1.0 – 0.8 | No inhibition; little or no phytotoxicity |
| 0.8 – 0.6 | Mild inhibition; minimal phytotoxicity |
| 0.6 – 0.4 | Strong inhibition; phytotoxic |
| ≤ 0.4 | Severe inhibition; phytotoxic |

**2.4.2 Seed germination and root elongation test using multiple plant species (Erikson et al., 1987; Leege & Thompson, 1997):**

No single plant species will exhibit consistent minimal or maximal sensitivity to all phytotoxins. Therefore, the use of several plant species in toxicity testing will help insure that variations in plant response to a given test substance will be detected. In general, the test consisted of: (i) obtaining an aqueous extract from each compost; (ii) exposing seeds to the compost water extracts for two to seven days (depending on the plant species); and (iii) determining seed germination and root elongation.

A sub-sample of each soil was mixed with deionized water (200 g type II DI water per 100 g soil; oven-dry weight basis); incubated at room temperature (ca. 22°C) for 3 h; filtered through cheesecloth and centrifuged for 15 min at 8000 *g* and 4°C; and filter-sterilized through 0.45-µm membrane filters (Gelman Scientific, Ann Arbor, MI). While maintaining aseptic conditions, 1.0 mL of extract was pipetted into replicate 50-mm sterile Petri dishes lined with filter paper (Whatman No. 1; 4.25 cm diameter) and 15–20 seeds (depending on size) placed in each dish. Each plant species was replicated 10 times and the Petri dishes incubated for seven to eleven days at 30°C in the dark. Seed germination was stopped by adding 1-mL 50% (v/v) ethanol to each dish. Treatments were evaluated by determining the number of germinated seeds and the length of the radicle.

**2.5 Compost Granulation:**

Granulation of the composts was accomplished using a table-top rolling pan granulator which was borrowed from The Potash Corporation of Saskatchewan Research lab. The process involves air drying and finely milling (100 mesh) the compost and then applying the compost to the pan of the granulator. The pan of the granulator rotates as the compost is applied. Water and/or *Rhizobium* culture is misted onto the compost, which causes the compost particles to stick together and form clumps. The clumps are broken up into smaller particles when they encounter a paddle that extends into the pan. The size of the granules is determined by the degree of tilt of the pan, and the depth that the paddle is placed. The

compost granules were air dried to a desired moisture content and sifted through screens to separate out granules of a desired size (1.2 mm diameter). Enough compost from each of the three sources (EA-1, PA-1, SZ-1) was granulated for use in the field trials and the growth chamber studies.

Samples of the peat and granulated products were sealed in self-sealing plastic bags and irradiated along with MBR commercial peats. Staff at MicroBioRhizogen arranged to include our compost samples in a regular shipment of their own peat sent to British Columbia for gamma irradiation

**2.6 Survival Studies:**

The products tested included EA-1, PA-1, SZ-1, peat granules (prepared in the same manner as compost granules), MBR-r granular inoculant, and LT-1 granular inoculant. Non-sterile and sterilized granules were inoculated and tested for *Rhizobium* survival.

Rhizobium cultures supplied my MicroBioRhizogen Corp., Saskatoon, where applied to the powdered and granulated composts (and peat in some experiments) as a mist. The carriers were mixed thoroughly and allowed to air dry before packaging.

Enough sample of each of the treatments was measured and sealed into Whirlpak bags for weekly sampling for 3 months and biweekly sampling until more than a one log drop in colony forming units was observed. A one log drop in numbers of colony forming units is used by the Canadian Food Inspection Agency for assessing the viability of commercial inoculant products (Marry Leggett, person. commun.).

On a sampling day, one package of each compost and commercial inoculant was removed from cold storage. The rest of the samples were returned to cold storage immediately. Serial dilutions of the inoculant samples were prepared, plated on yeast extract mannitol and incubated at 27°C for 6 days before counting. Colonies exhibiting the common morphological characteristics of rhizobia (off-white colonies covered with a slimy/gummy material) were distinguished from non-rhizobial colonies that appear dark red because of absorption of the Congo Red dye (Vincent, 1970).

**2.7 Nodulation Ability of Fresh and Stored Inoculants under Sterile Conditions:**

In addition to the plating studies, the inoculants were also examined for their ability to effectively nodulate pea under sterile conditions. Both freshly inoculated granules (same day) and stored (225 day old) inoculated granules were tested. Only the compost-based inoculants were freshly prepared in this experiment, the commercial products (MBR and LT) were purchased products that producers would use. The granular inoculant products were used to inoculate pea in sterile Leonard jars. These jars consist of nutrient solution in a

bottom reservoir that is wicked into a top chamber containing an inert rooting media (in our case sand). The entire apparatus was autoclaved, cooled, and then surface sterilized pea (*Pisum sativuum*, cv. Delta) seed and inoculant applied into the rooting media. Seed and inoculants were placed 2.5 cm into the sand. The Leonard jars were placed in a growth chamber. Sterile water was periodically added to replace water lost through evapo-transporation. Although the system is sterile to begin with, it cannot be maintained completely sterile for the duration of the experiment. However, because any indigenous rhizobia are killed in the initial sterilization process, any resulting nodulation can confidently be attributed to the introduced bacteria. Plants were harvested 6 weeks after emergence and analysed for nodulation, dry weights and shoot nitrogen contents.

**2.8 Growth chamber trials:**

Soil for the growth chamber trial was a clay-loam field soil low in N (<20 lb N/acre). The field from which it was collected had not been seeded to a pulse for three years.

Soil was weighed into the pots and the pots watered to 60% field capacity (wt/wt). One week later the pots were re-watered to field capacity and the treatments seeded. Four seeds of pea (cv Delta) or lentil (*Lens culinaris* cv Milestone) were seeded in each pot and subsequently thinned to two plants per pot.

Treatments for the study included: 1) Control (uninoculated); 2) MBR peat; 3) MBR granular; 4) EA inoculated powder sterile; 5) EA inoculated powder non-sterile; 6) EA inoculated granular non-sterile; 7) EA inoculated granular sterile; 8) EA uninoculated granular non-sterile; 9) EA uninoculated granular sterile; 10) PA inoculated powder non-sterile; 11) PA inoculated-powder sterile; 12) PA inoculated granular non-sterile; 13) PA inoculated granular sterile; 14) PA uninoculated granular non-sterile; 15) PA uninoculated granular sterile. Plants were harvested at two sampling dates (mid-flowering and late-flowering/pod-filling). The treatments with the two sampling dates were replicated four times. Pea and lentil were assessed in separate experiments. Because of space limitations, the two plant species had to be grown in separate chambers (and hence treated as separate experiments). Plants were watered to 60% field capacity as needed throughout the experiment.

Plants were assessed mid-season for nitrogenase activity, plant biomass, and total-N in the shoot. Yield data and total shoot and seed N was assessed at harvest along with biological N-fixation.

**2.9 Field Trials:**

The first field trials were seeded in May of 2001 using a small plot disc seeder with 12 inch row spacing. Two lentil (cv Milestone) and two pea (cv Delta) sites were established. The lentil sites were located near Clavet (Cargill site) and Conquest (Ray Cole, cooperator) and the pea sites near Clavet (Cargill site) and Rosthern (Seager Wheeler farm). Treatments at all sites included: EA-1 seed applied, PA-1 seed applied, SZ-1 seed applied, EA-1 granular, PA-1 granular, SZ-1 granular, MBR *SelfStick*, MBR granulated, and uninoculated controls. Plots were arranged in a randomized complete block design with 4 replicates. All sites were sampled mid-season (early July) for nitrogenase activity. Five plants per plot were dug up with intact roots and bulked for nitrogenase activity measurement (acetylene blockage method). Chromatographic analysis of gas samples were performed. Shoots, nodules and roots were oven dried for 24 h (65°C) and weighed separately. Plots were combined with a small plot combine in late August.

The second year of the field trials were conducted in 2002. Lentil plots were established at Conquest (Raymond Cole cooperator) and Dinsmore (Kirk Elliott cooperator). Pea plots were established at Rosthern (Seager Wheeler Farm) and Clavet (Cargill field site). The SZ-1 treatment was not included in this second field season, but additional treatments (comparable to the growth chamber treatments) were added for the two remaining composts. Treatments included: 1) Control (uninoculated); 2) MBR peat; 3) MBR granular; 4) EA inoculated powder sterile; 5) EA inoculated powder non-sterile; 6) EA inoculated granular non-sterile; 7) EA inoculated granular sterile; 8) EA uninoculated granular non-sterile; 9) EA uninoculated granular sterile; 10) PA inoculated powder non-sterile; 11) PA inoculated-powder sterile; 12) PA inoculated granular non-sterile; 13) PA inoculated granular sterile; 14) PA uninoculated granular non-sterile; 15) PA uninoculated granular sterile. The experiment was an RCBD with 4 blocks.

Mid-season sampling for nitrogenase activity was performed. Five plants per plot were dug up with intact roots and bulked for nitrogenase activity measurement (acetylene blockage method). Chromatographic analysis of gas samples was performed. Shoots, nodules and roots were oven dried and weighed separately.

Because of poor growth caused by the drought, final harvest samples were collected from 1 m x 1 m plots in each treatment rather than combining. It was felt that too much seed would be lost if the plots were combined. Harvest yield was determined and nitrogen content determined on the seed.

## 3.0 Results and Discussion

### 3.1 Chemical & physical analyses

#### 3.1.1 Initial characterizations

Characterizations for pH, EC, macronutrient and trace element (As, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Se, Zn) concentrations are summarized in Table 3.1 Additional analyses including nutrient ratios, solids, and water holding capacity are summarized in Table 3.2.

Whereas the peat samples exhibited a relatively narrow range of nutrient (macro- and micronutrients) concentrations, nutrient concentrations in the composts varied over a much wider range – reflecting the diversity of feedstocks used to produce the finished composts. In general, macronutrient concentrations were greater in the composts than in the peats – the two exceptions being nitrogen and sulfur. The total N content of composts whose feedstock included a high proportion of straw, leaves, or wood (i.e., the SZ-1, ME-1 and RSC-1 composts) were found to have a total N content ($0.35 \pm 0.11\%$) that was significantly lower than the peats ($1.59 \pm 0.22\%$) and composts whose feedstock contained lesser amounts of these materials (BC-1, PA-1, EA-1) ($1.37 \pm 0.13\%$). The sulfur content of the SZ-1, ME-1 and RSC composts ($0.95 \pm 0.42$ g $kg^{-1}$) was significantly lower than that of either of the peats ($2.75 \pm 0.49$ g $kg^{-1}$) or the cattle/swine manure composts ($3.63 \pm 0.76$ g $kg^{-1}$).

*Table 3.1. Chemical characterization of all of the compost sample initially screened.*

| | Element | Max. Trace Element Conc.* | Composts | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ----- Peat ----- | | Swine manure | --- Cattle manure --- | | Zoopoo™ | Yard waste & animal bedding | Yard & food wastes | |
| Symbol | Name | | MBR-r | LT-1 | BC-1 | PA-1 | EA-1 | SZ-1 | ME-1 | RCS-1 | RSC-1e |
| | pH | | 6.63 | 4.48 | 5.64 | 7.13 | 7.00 | 7.31 | 7.66 | 8.61 | 8.36 |
| | EC (dS $m^{-1}$) | | 1.40 | 0.65 | 10.69 | 1.84 | 5.12 | 2.58 | 1.47 | 2.27 | 2.83 |
| N | Nitrogen (%) | | 1.74 | 1.43 | 1.51 | 1.28 | 1.31 | 0.31 | 0.48 | 0.27 | 1.63 |
| | | | mg $kg^{-1}$ | | | | | | | | |
| P | Phosphorus | | 520 | 670 | 12700 | 7200 | 7500 | 1100 | 1400 | 820 | 2700 |
| K | Potassium | | 4600 | 2000 | 23200 | 17600 | 20300 | 9400 | 10700 | 4900 | 6300 |
| Ca | Calcium | | 23300 | 10600 | 17700 | 31400 | 40400 | 37200 | 29200 | 26900 | 23200 |
| Mg | Magnesium | | 3500 | 2600 | 6600 | 10000 | 10000 | 19600 | 9800 | 10700 | 3900 |
| S | Sulfur | | 3100 | 2400 | 4500 | 3100 | 3300 | 740 | 1200 | 480 | 1400 |
| B | Boron | | 11 | 11 | 30 | 21 | 15 | 17 | 16 | 12 | <1 |
| Cl | Chloride | | 400 | 500 | 10200 | 4800 | 8000 | 700 | 2400 | 400 | 6000 |
| Co | Cobalt | 34 | 6.9 | 4.2 | 1.0 | 7.4 | 6.2 | 9.5 | 6.2 | 7.1 | 2.7 |
| Cu | Copper | 100 | 16 | 13 | 120 | 55 | 52 | 18 | 14 | 20 | 13 |
| Fe | Iron | | 11200 | 7600 | 1600 | 14200 | 10700 | 22000 | 14500 | 16900 | 5600 |
| Mn | Manganese | | 95 | 80 | 290 | 330 | 360 | 390 | 320 | 370 | 200 |
| Mo | Molybdenum | 5 | 4.5 | 1.7 | 4.3 | 5.8 | 3.5 | 6.0 | 2.8 | 2.7 | <0.5 |
| Ni | Nickel | 62 | 17 | 9.7 | 6.2 | 14 | 11 | 19 | 13 | 15 | 7.2 |
| Zn | Zinc | 500 | 50 | 25 | 490 | 230 | 250 | 82 | 56 | 78 | 58 |
| Al | Aluminum | | 28100 | 15800 | 680 | 18200 | 17600 | 31800 | 15700 | 18600 | 6000 |
| As | Arsenic | 13 | 5.1 | 3.1 | 0.6 | 3.9 | 3.1 | 6.3 | 5.0 | 6.0 | 1.8 |
| Ba | Barium | | 220 | 160 | 27 | 210 | 220 | 260 | 210 | 190 | 120 |
| Be | Beryllium | | 0.8 | 0.5 | <0.5 | 0.6 | 0.5 | 1.0 | 0.5 | 0.6 | <0.5 |
| Cd | Cadmium | 3 | 1.0 | 1.1 | <0.5 | 1.2 | 1.1 | 1.8 | 1.2 | 1.4 | 0.6 |
| Cr | Chromium | 210 | 26 | 24 | 15 | 48 | 35 | 38 | 60 | 60 | 47 |
| Pb | Lead | 150 | 6 | 16 | <1 | 5 | 5 | 13 | 8 | 12 | 3 |
| Hg | Mercury | 0.8 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Se | Selenium | 2 | 0.6 | <0.5 | <0.5 | <0.5 | <0.5 | 0.6 | <0.5 | <0.5 | <0.5 |
| Ag | Silver | | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Na | Sodium | | 520 | 140 | 5900 | 2900 | 4100 | 670 | 1300 | 600 | 4000 |
| Sr | Strontium | | 200 | 33 | 60 | 78 | 64 | 66 | 64 | 45 | 35 |
| Ti | Titanium | | 760 | 650 | 35 | 710 | 390 | 1000 | 620 | 630 | 270 |
| V | Vanadium | | 55 | 30 | 4.7 | 46 | 34 | 67 | 40 | 45 | 16 |
| Zr | Zirconium | | 22 | 13 | 1.3 | 6.4 | 4.7 | 24 | 15 | 16 | 4.7 |

* The maximum allowable trace element concentration allowed under the National Standard of Canada: *Organic Soil Conditioners – Composts* (Bureau de normalisation du Québec; BNQ) and adopted by the Canadian Council of Ministers of the Environment (CCME: *Guidelines for Compost Quality*).

*Table 3.2 Additional chemical and physical characteristics of peat and compost samples.*

| | Peats | | Composts and feedstocks | | | | |
|---|---|---|---|---|---|---|---|
| | | | Swine manure | Cattle manure | | Zoopoo™ | Yard waste & animal bedding |
| **Symbol / Name** | **MBR-r** | **LT-1** | **BC-1** | **PA-1** | **EA-1** | **SZ-1** | **ME-1** |
| TOC (%) | 32.9 | 30.9 | 39.9 | 12.0 | 20.0 | 5.97 | 7.72 |
| TN (%) | 2.07 | 1.37 | 1.92 | 1.36 | 1.66 | 0.48 | 0.53 |
| TS (%) | 0.49 | 0.32 | 0.67 | 0.30 | 0.41 | 0.044 | 0.066 |
| C:N ratio | 16:1 | 23:1 | 21:1 | 9:1 | 12:1 | 12:1 | 15:1 |
| C:S ratio | 67:1 | 97:1 | 60:1 | 40:1 | 49:1 | 136:1 | 117:1 |
| N:S ratio | 4:1 | 4:1 | 3:1 | 5:1 | 4:1 | 11:1 | 8:1 |
| Sodium (Na; mg $kg^{-1}$) | 520 | 140 | 5900 | 2900 | 4100 | 670 | 1300 |
| Chloride (Cl; mg $kg^{-1}$) | 400 | 500 | 10200 | 4800 | 8000 | 700 | 2400 |
| EC (ds $m^{-1}$) | 1.40 | 0.65 | 10.69 | 1.84 | 5.12 | 2.58 | 1.47 |
| Total solids (%) | 96.7 | 56.0 | 70.8 | 54.9 | 55.6 | 68.7 | 69.0 |
| Biodegradable volatile solids[a] (%) | 55.3 | 63.2 | 84.0 | 26.1 | 44.0 | 22.2 | 17.7 |
| Ash content[a] (%) | 44.7 | 36.8 | 16.0 | 73.9 | 56.0 | 77.8 | 82.3 |
| Water holding capacity (%) | >100 | 81 | 50 | 69 | 62 | 41 | 33 |

[a] Calculated as a percentage of the total solids.

With only a few exceptions, micronutrient concentrations in the composts and peats were generally comparable. The primary exception to this being chloride, which was present at much higher concentrations in the composts – a reflection of the fact that animal wastes (urine and feces) naturally contain high salt concentrations. Manganese and zinc concentrations also were greater in the composts than the peats – again, reflecting the animal origins of the feedstocks. Trace element concentrations in the composts and peats exhibited considerable overlap and, in general, were not significantly different. Indeed, the only real difference in trace metal concentrations was observed for sodium (a major cationic component of animal urine), which was present at higher concentrations in several of the composts. The high Na and Cl concentrations in the BC-1 and EA-1 composts are reflected in the relatively high electrical conductivity (EC) values recorded for these samples (Table 3.2). Electrical conductivities in excess of 5 dS $m^{-1}$ indicate a potential for salt damage

(Larcher, 1983).

The National Standard of Canada [*Organic Soil Conditioners – Composts* by the Bureau de normalisation du Québec (BNQ) and adopted by the Canadian Council of Ministers of the Environment (CCME: *Guidelines for Compost Quality*)] identifies 11 trace metals subject to concentration restrictions (As, Co, Cu, Cd, Cr, Hg, Mo, Ni, Pb, Se, and Zn) in composts/organic amendments. The maximum trace element concentrations allowable for a compost (or any other organic amendment) to be classified as 'Type AA' (BNQ) or 'Category A' (CCME) – suitable for unrestricted use in agriculture, horticulture and residential gardens – are listed in Table 3.1. Only copper, molybdenum and zinc were detected at levels in excess of those allowable in Type AA compost (and, then in only a few samples). Molybdenum concentrations were only marginally high in two of the composts In Concentrations of copper and zinc are considerably lower than the acceptable limits for 'Type B' compost, which is suitable for agricultural use provided the annual application rate does not exceed 75 kg Cu $ha^{-1}$ $yr^{-1}$ or 140 kg Zn $ha^{-1}$ $yr^{-1}$ (CCC, 1998; Leege & Thompson, 1997) – a rate well in excess of that which would be applied in the form of an inoculant carrier.

Both the SZ-1 and ME-1composts (whose feedstocks included a high proportion of straw, leaves, or wood) were characterized by total organic carbon, total N, and total S contents well below those of the other composts and the peats (Table 3.2). Whereas the total N content of the two cattle manure composts (PA-1 and EA-1) was in the same range as that of the two peats (MBR-r and LT-1), the total organic carbon content of both composts was significantly less than that of the peats. Consequently, the composts were characterized by C:N ratios about 25 to 60% lower than those of the peats. With the exception of the Zoopoo™ compost (SZ-1), a similar trend was observed for the C:S ratio. Whereas the N:S ratio of the cattle manure composts was about the same as that of the peats (ca. 4:1), the N:S ratio of the SZ-1 compost was significantly higher (11:1).

The total solids content of the composts was in the same range as that of the peats. The ash content of the composts, however, was significantly greater than that of the peats (Table 3.2). This is primarily a reflection of the fact that the peats contain considerably greater amounts of readily biodegradable organic matter – which is reflected in the 'biodegradable volatile solids' fraction of the composts. In addition, the ash content of the composts contains a contribution from the inorganic soil components that are frequently mixed (to varying degrees) with the organic feed-stocks (Note: soils are frequently used as a source of inoculum for composting). The low organic matter content of the composts also is reflected in the lower water holding capacity of these materials – relative to the peats.

### 3.1.2 Batch comparisons:

New supplies of the PA-1, EA-1, and SZ-1 compost were obtained in large quantities for further testing in greenhouse and field studies. These new sources (identified as Batch 2) were characterized chemically and physically to determine if there are any major differences between batches of the same product. For comparison, results of the chemical characterization of both batches are included in Table 3.3.

***Table 3.3 Chemical characteristics of the compost samples from batches obtained at different times.***

| | | | Batch 1 | | | Batch 2 | | |
|---|---|---|---|---|---|---|---|---|
| Symbol | Name | | PA-1 | EA-1 | SZ-1 | PA-1 | EA-1 | SZ-1 |
| | pH | | 7.13 | 7.00 | 7.31 | 7.15 | 6.98 | 7.25 |
| | EC (dS $m^{-1}$) | | 1.84 | 5.12 | 2.58 | 2.21 | 4.65 | 2.37 |
| | TOC (%) | | 12.0 | 20.0 | 5.97 | 12.4 | 20.0 | 6.2 |
| | TS (%) | | 0.30 | 0.41 | 0.04 | 0.1 | 0.22 | 0.01 |
| | TN (%) | | 1.4 | 1.7 | 0.5 | 1.4 | 1.6 | 0.6 |
| N | Nitrogen (%) | | 1.28 | 1.31 | 0.31 | 1.29 | 1.57 | 0.48 |
| P | Phosphorus | | 7200 | 7500 | 1100 | 9170 | 9790 | 1190 |
| K | Potassium | | 17600 | 20300 | 9400 | 14200 | 24000 | 7640 |
| Ca | Calcium | | 31400 | 40400 | 37200 | 34400 | 42900 | 21200 |
| Mg | Magnesium | | 10000 | 10000 | 19600 | 9100 | 10200 | 9750 |
| S | Sulfur | | 3100 | 3300 | 740 | nd | nd | nd |
| B | Boron | | 21 | 15 | 17 | | | |
| Cl | Chloride | | 4800 | 8000 | 700 | 960 | 5900 | 630 |
| Co | Cobalt | 34 | 7.4 | 6.2 | 9.5 | 7 | 6 | 8 |
| Cu | Copper | 100 | 55 | 52 | 18 | 54 | 47 | 20 |
| Fe | Iron | | 14200 | 10700 | 22000 | 13200 | 10100 | 19300 |
| Mn | Manganese | | 330 | 360 | 390 | 380 | 360 | 410 |
| Mo | Molybdenum | 5 | 5.8 | 3.5 | 6.0 | 2 | 3 | <1 |
| Ni | Nickel | 62 | 14 | 11 | 19 | 16 | 15 | 20 |
| Zn | Zinc | 500 | 230 | 250 | 82 | 256 | 236 | 99.8 |
| Al | Aluminum | | 18200 | 17600 | 31800 | 17200 | 9270 | 24100 |
| As | Arsenic | 13 | 3.9 | 3.1 | 6.3 | 4.4 | 3.8 | 5.8 |
| Ba | Barium | | 210 | 220 | 260 | 219 | 227 | 243 |
| Be | Beryllium | | 0.6 | 0.5 | 1.0 | <1 | <1 | <1 |
| Cd | Cadmium | 3 | 1.2 | 1.1 | 1.8 | <0.5 | <0.5 | <0.5 |
| Cr | Chromium | 210 | 48 | 35 | 38 | 25.4 | 21.7 | 31.1 |
| Pb | Lead | 150 | 5 | 5 | 13 | 7 | 6 | 16 |
| Hg | Mercury | 0.8 | <0.05 | <0.05 | <0.05 | nd | nd | nd |
| Se | Selenium | 2 | <0.5 | <0.5 | 0.6 | 2.1 | 0.2 | <0.1 |
| Ag | Silver | | <0.5 | <0.5 | <0.5 | <1 | <1 | <1 |
| Na | Sodium | | 2900 | 4100 | 670 | 2000 | 3600 | 400 |
| Sr | Strontium | | 78 | 64 | 66 | 79 | 66 | 63 |
| Ti | Titanium | | 710 | 390 | 1000 | 185 | 70 | 173 |
| V | Vanadium | | 46 | 34 | 67 | 43 | 32 | 53 |
| Zr | Zirconium | | 6.4 | 4.7 | 24 | 15 | 9 | 21 |

The maximum allowable trace element concentration allowed under the National Standard of Canada: *Organic Soil Conditioners – Composts* (Bureau de normalisation du Québec; BNQ) and adopted by the Canadian Council of Ministers of the Environment (CCME: *Guidelines for Compost Quality*).

There were no striking differences between the chemical properties for the two batches of the different composts. Indeed, molybdenum concentrations that were identified as being slightly high in Batch 1 were within acceptable levels in Batch 2. In terms of the nutrient elements (N through Zn;), the SZ compost had the lowest levels of most elements compared to the PA and EA composts and was overall most similar to the peat products (Table 3.1). The SZ compost also had the lowest sodium concentration of the three composts. High sodium levels can affect electrical conductivity, which in turn can negatively affect seed germination and growth.

### 3.2 Microbial characterizations:

Both the 'sterile' (i.e., gamma-irradiated) and non-sterile peat obtained from MicroBio RhizoGen (MBR-s and MBR-r) yielded the lowest numbers of cultureable microorganisms (Table 3.4). Moreover, though populations of total heterotrophic bacteria were similar ($5.0 \times 10^5$ cfu/g peat) in both the non-sterile and sterile peats, fungi and actinomycetes were detected in the non-sterile (raw) peat only. Both the MBR peat samples were free of *Enterobacteriaceae* and presumptive *Klebsiellae*. The peat sample obtained from LiphaTech, however, yielded detectable populations of *Enterobacteriaceae* and presumptive *Klebsiellae* – as well as populations of total heterotrophs, fungi, and actinomycetes that were one- to two-orders of magnitude greater than those detected in the MBR peat.

Populations of total heterotrophic bacteria, total fungi and actinomycetes enumerated from the horticultural grade compost marketed by EcoAg Initiatives (EA-1 and EA-2p) were similar to those found in the LT-peat. In addition, populations of *Enterobacteriaceae* and presumptive *Klebsiellae* were detected in the granular compost (EA-1), but were absent from the pelleted compost (EA-2p). Presumably, this difference is a result of the pelleting process itself (i.e., a combination of temperature and pressure stress during pelleting). In general, microbial populations in the 'sterile' and non-sterile composted cattle manure from Corcan Agribusiness (PA-s and PA-r) were similar to those found in both the EcoAg compost and LT-peat. Likewise, for each of the individual microbial populations assessed, the mixed yard/animal waste compost from the Moose Jaw Exhibition (ME-1), swine manure compost from Duncan Farms (BC-1), and mixed horticultural/animal waste compost from the Forestry Farm Park (SZ-1) yielded population numbers that were similar to one another and to the LT-peat (Table 3.4).

Both size and diversity of a soil microbial population are known to be influenced by the water status of the soil. Therefore, population differences between the various peats and composts may reflect the differences in initial water content (i.e., the water content during storage). For example, whereas the MBR-peat had a water content of about 13%, the water content of the LT-peat was ca. 49%. The water contents of the different composts were

generally in the range of 35–45%. Thus, the higher population counts recorded for the LT-peat and the composts may, in part, reflect the more favorable water status of these materials.

***Table 3.4 Cultureable total heterotroph, Enterobacteriaceae, presumptive Klebsiellae, total fungi and actinomycete populations (cfu·g$^{-1}$) isolated from composts and peat on selective culture medium (mean values: n = 6).***

| Sample | Tryptic Soy Agar | MacConkey Agar | MacConkey-IS Agar | Czapec-Dox Agar | Actinomycete Agar |
|---|---|---|---|---|---|
| | Colony forming units (cfu) | | | | |
| MBR-r | $5.0 \times 10^5$ | 0.0 | 0.0 | $6.5 \times 10^4$ | $1.5 \times 10^3$ |
| MBR-s | $5.0 \times 10^5$ | 0.0 | 0.0 | 0.0 | 0.0 |
| LT-1r | $1.5 \times 10^8$ | $6.5 \times 10^3$ | $2.5 \times 10^2$ | $6.0 \times 10^5$ | $6.9 \times 10^5$ |
| BC-1 | $1.2 \times 10^8$ | $1.2 \times 10^5$ | $4.0 \times 10^2$ | $2.8 \times 10^4$ | $8.8 \times 10^4$ |
| PA-1r | $5.2 \times 10^7$ | $4.5 \times 10^4$ | $1.5 \times 10^5$ | $3.5 \times 10^3$ | $1.5 \times 10^6$ |
| PA-1s | $2.7 \times 10^6$ | $7.5 \times 10^3$ | $4.9 \times 10^3$ | $1.0 \times 10^3$ | $2.4 \times 10^6$ |
| EA-2p | $2.5 \times 10^8$ | 0.0 | 0.0 | $2.0 \times 10^4$ | 0.0 |
| EA-1 | $2.0 \times 10^7$ | $5.5 \times 10^7$ | $1.0 \times 10^5$ | $3.5 \times 10^3$ | $1.4 \times 10^6$ |
| SZ-1 | $3.5 \times 10^8$ | $5.0 \times 10^2$ | $1.0 \times 10^3$ | $2.5 \times 10^3$ | $1.5 \times 10^4$ |
| ME-1 | $1.5 \times 10^8$ | $1.0 \times 10^6$ | $1.1 \times 10^5$ | $7.5 \times 10^3$ | $1.1 \times 10^6$ |
| RSC-1 | $2.1 \times 10^9$ | $2.1 \times 10^6$ | $9.1 \times 10^6$ | $1.4 \times 10^4$ | $> 10^7$ |
| RSC-1e | $5.0 \times 10^{10}$ | $1.7 \times 10^6$ | $> 10^{10}$ | $1.8 \times 10^5$ | $> 10^7$ |
| RSC-2 | $2.0 \times 10^9$ | $4.9 \times 10^5$ | $7.0 \times 10^4$ | $> 10^7$ | $2.5 \times 10^4$ |
| RSC-2e | $1.4 \times 10^{10}$ | $> 10^{10}$ | $> 10^{10}$ | $> 10^7$ | $2.3 \times 10^5$ |

Tryptic Soy Agar: enumeration of total heterotrophic bacteria.

MacConkey's Agar: enumeration of total *Enterobacteriaceae*.

MacConkey-Inositol-Carbenicillin Agar: used to separate presumptive *Enterobacteriaceae* and non-*Enterobacteriaceae*.

Czapeck-Dox Agar: enumeration of total fungi.

Actinomycete Agar: enumeration of total actinomycete populations.

Composts from the Saskatoon Regional Psychiatric Centre (RSC, RSC-E, RSC-2, and RSC-2E) yielded populations of total heterotrophs ($\geq 10^9$ cfu/g), total fungi ($10^4$–$10^7$ cfu/g), and actinomycetes ($10^4$–$10^7$ cfu/g) that were generally two- to three-orders of magnitude greater than those enumerated from the peats or other composts. The RSC-composts also yielded populations of *Enterobacteriaceae* ($10^5$–$10^{10}$ cfu/g) and presumptive *Klebsiellae* ($10^5$–$10^{10}$ cfu/g) that were significantly greater than average populations. It is reasonable to assume that these numbers reflect the fact that the RSC-composts contain food waste, which could be expected to have higher indigenous populations of presumptive human pathogenic

bacteria (e.g., the *Enterobacteriaceae* and *Klebsiellae*). In addition, however, the large fungal populations characteristic of these composts are an indication that the composting process was incomplete – presumably a reflection of the accelerated *in-vessel* composting process employed at the Centre and incomplete curing of the compost.

Though these results demonstrate that putative human pathogenic organisms are present in the composts, they also indicate that (i) these organisms also are found in naturally occurring peats and (ii) populations of these pathogens can be significantly reduced, or even eliminated, by proper pretreatment ("sterilization') of the compost. Our results provide important information on disease potential when handling selected commercial composts.

### 3.2.1 Incidence of soil entero-pathogens (fecal coliforms):

Though presumptive human pathogenic bacteria (Table 3.4) and fecal coliforms (Table 3.5) were isolated from all composts, the presence of fecal coliforms was confirmed in only 6 of the 12 samples (Table 3.5). Not surprisingly, the highest incidence of fecal coliforms was detected in the food waste compost that had been processed in the in-vessel composter and windrowed for only about six weeks (i.e., RSC-1e). Fecal coliforms also were detected in the food waste compost that had been windrowed for 1-year (RSC-1), the mixed yard/animal waste compost from the Moose Jaw Exhibition (ME-1), the granular cattle manure compost (EA-1), and the swine manure compost (BC-1). Interestingly, fecal coliforms also were detected in the peat sample provided by LiphaTech – and currently used as a carrier for commercial *Rhizobium* inoculants. No fecal coliforms were found in either the MBR-peat; pelleted, horticultural grade compost from EcoAg (EA-2p); or mixed horticultural/animal waste compost from Forestry Farm Park (SZ-1).

Given the nature of the feedstocks (e.g., manures and food wastes) and the different methods used to compost these materials (i.e., short-term, in-vessel composting vs. long-term, windrow composting), the presence of pathogenic organisms in some of the composts is not totally unexpected. Moreover, with the exception of the RSC-1e compost (short-term in-vessel compost from food wastes), the numbers of confirmed fecal coliforms present in the composts was well below the limit (i.e., >1000 MPN $g^{-1}$ solids, dry-weight basis) identified in the National Standard of Canada [*Organic Soil Conditioners – Composts* by the Bureau de normalisation du Québec (BNQ)] and adopted by the Canadian Council of Ministers of the Environment (CCME: *Guidelines for Compost Quality*). Indeed, only the RSC-1e compost yielded numbers of fecal coliforms (1321 MPN $g^{-1}$ solids) greater than the BNQ and CCME allowable number.

*Table 3.5. Presumptive and confirmatory tests of fecal coliforms in the peat and compost samples.*

| Sample | Presumptive (LTB) | | Confirmatory (ECM) | |
|---|---|---|---|---|
| | MPN* | | MPN* | |
| | (per 100 mL) | (per g dry solids) | (per 100 mL) | (per g dry solids) |
| MBR-r | 23 | 0.02 | 0 | 0 |
| MBR-s | 49 | 0.05 | 0 | 0 |
| LT-r | 3,126 | 3.1 | 69 | 0.07 |
| BC-1 | 23 | 0.02 | 7.7 | 0.01 |
| EA-1 | 23 | 0.02 | 4.4 | < 0.01 |
| EA-2p | 23 | 0.02 | 0 | 0 |
| PA-1r | 23 | 0.02 | 0 | 0 |
| PA-1s | 23 | 0.02 | 0 | 0 |
| SZ-1 | 23 | 0.02 | 0 | 0 |
| ME-1 | 4,532 | 4.5 | 107 | 0.11 |
| RSC-1 | 1,312,535 | 1321 | 49 | 0.05 |
| RSC-1e | 1,312,535 | 1321 | 1,312,535 | 1321 |

* The National Standard of Canada states that the quantity of fecal coliforms must be <1000 MPN $g^{-1}$ total solids (dry-weight basis).

### 3.2.2 Species Identification:

In all, 21 bacterial species were identified from the peat (8 cfu's) and compost (13 cfu's) samples. Of the 17 species identified, only three species (*Nocardia globerula, Bacillus megaterium, and Brevibacillus brevis*) were found to be common to both the peat and compost samples. This suggests that there is a considerable degree of diversity associated with the various composts, and that the types of indigenous bacteria associated with a particular compost are most likely a reflection of the feedstock used to produce the compost. In turn, this suggests that composts are capable of supporting a wide variety of microorganisms (including rhizobia).

*Table 3.6. Characterization of environmental bacteria present in the peats and composts. Bacteria were isolated and grown on TSA before being identified using fatty acids methyl ester profiles - MIDI.*

| Compost ID | Isolate No. | Identification | MIDI similarity index |
|---|---|---|---|
| *MBR-r* | 15957 | *Bacillus megaterium* | 0.581 |
| | 15958 | *Brevibacillus brevis* | 0.598 |
| | 15961 | *Staphylococcus kloosii* | 0.397 |
| | 15881 | *Cellulomonas flavigena* | 0.640 |
| | 15920 | *Kocuria varians* | 0.710 |
| *LT-1* | 15888 | *Pseudomonas balearica* | 0.783 |
| | 15917 | *Nocardia globerula* | 0.541 |
| | 15919 | *Nocardia restricta* | 0.308 |
| *PA-1* | 15876 | *Arthrobacter oxydans* | 0.553 |
| | 15960 | *Arthrobacter atrocyaneus* | 0.514 |
| | 15869 | *Nesterenkonia halobia* | 0.778 |
| | 15877 | *Arthrrobacter ilicis* | 0.564 |
| | 15962 | *Arthrobacter ilicis* | 0.674 |
| | 15956 | *Paenibacillus gordonae* | 0.630 |
| *EA-1* | 15938 | *Clavibacter michiganense* | 0.823 |
| | 15953 | *Nocardia globerula* | 0.500 |
| | 15871 | *Paenibacillus pabuli* | 0.667 |
| | 15948 | *Brevibacillus brevis* | 0.520 |
| *SZ-1* | 15880 | *Bacillus firmis* | 0.564 |
| | 15937 | *Microbacterium esteraromaticum* | 0.827 |
| | 15949 | *Bacillus megaterium* | 0.580 |

### 3.3 Phytotoxicity (Seed Germination & Root Elongation):

Early plant growth is often rapid; consequently, seedlings generally exhibit high levels of metabolic activity and, as a result, the early stages in a plant's development are often more sensitive to the presence of potentially toxic chemicals than are the later stages of plant growth (Erikson et al., 1987). Thus, seed germination and root elongation assays have been developed to provide reliable indications of the presence of significant quantities of phytotoxic compounds in a test matrix (e.g., soil or compost).

#### 3.3.1 Cress phytotoxicity bioassay:

Because of its small seed size, high rate of germination, and sensitivity to environmental stress, garden cress is a common indicator plant used for assessing phytotoxicity. Bioassay results for the compost:water extracts are summarized in Table 3.7. There were significant phytotoxic effects associated with both the PA-1 and EA-1 composts – especially in the undiluted extracts. Though seed germination in the extracts from the PA-1 compost was essentially the same as that in the control system, root elongation in the compost extracts was reduced. In extracts from the EA-1 compost, on the other hand, both seed germination and

root elongation were negatively impacted. In both cases, reductions in the germination index were greatest in the undiluted extracts. Moreover, diluting the extracts with deionized water resulted in higher rates of germination and/or slightly longer root lengths (Table 3.7).

The EA-1 compost had an EC value of about 5 dS $m^{-1}$ (Table 3.2), indicating that reductions in the germination index were most likely a result of salt stress. Likewise, the PA-1 compost contained relatively high concentrations of both sodium (Na) and chloride (Cl) (Table 3.2) – again suggesting that salt effects were the most likely cause of the reduced germination indices in the compost extracts.

Although there were no significant differences in the number of seeds that germinated in the control and water extracts from the SZ-1 compost, seeds that germinated in the compost extracts produced roots that were generally shorter than those in the control. Nevertheless, the resulting germination indices for the SZ-1 extracts indicated no phytotoxic response (Table 3.7). This result is consistent with the fact that the SZ-1 compost contained only small amounts of Na and Cl and was characterized by a relatively low EC value.

The two commercial peat samples were not classified as inhibitory in the garden cress assay. Similar to the compost samples, root elongation was reduced somewhat in all but the 1:4 dilution of the MBR peat sample, but not enough to attain a germination index below 0.80.

### 3.3.2 Multiple species seed germination and root elongation tests:

Different plant species exhibit different degrees of chemical sensitivity and no one species is suitable for testing under all conditions. Thus, in addition to the garden cress bioassays, standard seed germination and root elongation tests (Erikson et al., 1987) using several different plant species were conducted in the compost:water extracts. Because phytotoxicity was expected to involve plant response to salt concentration, plants varying in their salt tolerance were chosen for inclusion in this study. Results of the bioassays are summarized in Table 3.8.

***Table 3.7. Garden cress bioassay. Seed germination and radicle length were determined following a 24 h incubation at 27℃ in the dark.***

| Compost | Dilution | Seed Germination -- Mean[a] -- No. | % | PRG[b] (%) | Root Elongation Mean (mm) | PRRL[c] (%) | GI[d] | Interpretation |
|---|---|---|---|---|---|---|---|---|
| *Control ($H_2O$)[e]* | *Undiluted* | *24.5* | *98.0* | --- | *11.44* | --- | --- | --- |
| PA-1 | Undiluted | 23.8 | 95.2 | 97.1 | 3.99 | 34.9 | 0.34 | Severe inhibition |
| | 1:2 | 24.8 | 99.2 | 101.2 | 8.26 | 72.2 | 0.73 | Mild inhibition |
| | 1:4 | 24.7 | 98.8 | 100.8 | 8.40 | 73.4 | 0.74 | Mild inhibition |
| EA-1 | Undiluted | 9.6 | 38.4 | 39.2 | 1.41 | 12.3 | 0.05 | Severe inhibition |
| | 1:2 | 24.4 | 97.6 | 99.6 | 5.78 | 50.5 | 0.50 | Strong inhibition |
| | 1:4 | 24.8 | 99.2 | 101.2 | 9.11 | 79.6 | 0.81 | No inhibition |
| SZ-1 | Undiluted | 24.5 | 98.0 | 100.0 | 9.69 | 84.7 | 0.85 | No inhibition |
| | 1:2 | 24.4 | 97.6 | 99.6 | 10.67 | 93.3 | 0.93 | No inhibition |
| | 1:4 | 24.7 | 98.8 | 100.8 | 11.06 | 96.7 | 0.97 | No inhibition |
| *Control ($H_2O$)* | *Undiluted* | *24.7* | *98.8* | --- | *9.8* | --- | --- | --- |
| MBR-1 | Undiluted | 24.4 | 97.6 | 98.8 | 8.5 | 86.7 | 0.86 | No inhibition |
| | 1:2 | 24.7 | 98.8 | 100 | 7.9 | 80.6 | 0.81 | No inhibition |
| | 1:4 | 24.8 | 99.2 | 100.4 | 10.7 | 109.2 | 1.10 | No inhibition |
| LT-1 | Undiluted | 24.8 | 99.2 | 100.4 | 7.8 | 79.6 | 0.80 | No inhibition |
| | 1:2 | 24.6 | 98.4 | 99.6 | 9.7 | 99.0 | 0.80 | No inhibition |
| | 1:4 | 24.7 | 98.8 | 100 | 7.8 | 79.6 | 0.80 | No inhibition |

[a] Percent (%) germination: calculated relative to the total number of seeds (25) placed in each Petri dish.

[b] Percent relative germination: PRG = (MGT/MGC)×100; where MGC = mean germination in the water control; MGT = mean germination in the compost extracts.

[c] Percent relative radicle length: PRRL = (MRLT/MRLC)×100; where MRLC = mean radicle length of seeds germinated in the water control; MRLT = mean radicle length of seeds germinated in the compost extracts.

[d] Zucconi's germination index: $GI = (PRG \times PRRL)/10^4$.

[e] Separate controls were used for the composts and peat samples

*Table 3.8. Multiple plant species bioassay results.*

| Plant | Medium | Seed Germination -- Mean[a] -- No. | % | PRG[b] (%) | Root Elongation Mean (mm) | PRRL[c] (%) | GI[d] | Interpretation |
|---|---|---|---|---|---|---|---|---|
| Cucumber | Control ($H_2O$) | 6 | 40 | - - - | 4.46 | - - - | - - - | |
| | PA-1 | 3 | 20 | 50.0 | 11.14 | 249.8 | 1.25 | No inhibition |
| | EA-1 | 2 | 13 | 32.5 | 10.00 | 224.2 | 0.73 | Mild inhibition |
| | SZ-1 | 4 | 27 | 67.5 | 5.82 | 130.5 | 0.88 | No inhibition |
| | Control ($H_2O$) | 14.7 | 98 | - | 33.5 | - | - | - |
| | MBR-1 | 14.5 | 96.6 | 98.6 | 21.7 | 64.8 | 0.64 | Mild inhibition |
| | LT-1 | 14.6 | 97.3 | 99.2 | 32.7 | 97.6 | 0.97 | No inhibition |
| Wheat | Control ($H_2O$) | 13 | 65 | - - - | 21.86 | - - - | - - - | |
| (CDC Bounty) | PA-1 | 16 | 80 | 123.1 | 17.68 | 80.9 | 1.00 | No inhibition |
| | EA-1 | 12 | 60 | 92.3 | 14.49 | 66.3 | 0.61 | Mild inhibition |
| | SZ-1 | 15 | 75 | 115.4 | 21.52 | 98.4 | 1.14 | No inhibition |
| | Control ($H_2O$) | 19.3 | 96.5 | - | 15.8 | - | - | - |
| | MBR-1 | 18.9 | 94.6 | 97.9 | 20.9 | 132.3 | 1.30 | No inhibition |
| | LT-1 | 19.0 | 95 | 98.4 | 18.2 | 115.2 | 1.13 | No inhibition |
| Hull-less Barley | Control ($H_2O$) | 18 | 90 | - - - | 18.02 | - - - | - - - | |
| (CDC Freedom) | PA-1 | 18 | 90 | 100.0 | 15.24 | 84.6 | 0.85 | No inhibition |
| | EA-1 | 17 | 85 | 94.4 | 10.25 | 56.9 | 0.54 | Strong inhibition |
| | SZ-1 | 17 | 85 | 94.4 | 19.31 | 107.2 | 1.01 | No inhibition |
| | Control ($H_2O$) | 18.5 | 92.5 | - | 21.4 | - | - | - |
| | MBR-1 | 17.5 | 87.5 | 94.6 | 16.7 | 78.0 | 0.74 | Mild inhibition |
| | LT-1 | 17.9 | 89.5 | 96.7 | 16.2 | 75.7 | 0.73 | Mild inhibition |
| Bean | Control ($H_2O$) | 11 | 73 | - - - | 23.82 | - - - | - - - | |
| (Blue Lake | PA-1 | 10 | 67 | 91.8 | 27.85 | 116.9 | 1.07 | No inhibition |
| Stringless) | EA-1 | 10 | 67 | 91.8 | 24.34 | 102.2 | 0.94 | No inhibition |
| | SZ-1 | 12 | 80 | 109.6 | 20.35 | 85.4 | 0.94 | No inhibition |
| | Control ($H_2O$) | 9.0 | 6.0 | - | 18.5 | - | - | - |
| | MBR-1 | 7.9 | 52.7 | 88.3 | 31.0 | 167.6 | 1.48 | No inhibition |
| | LT-1 | 9.8 | 65.3 | 108.3 | 31.7 | 171.4 | 1.86 | No inhibition |

[a] Percent (%) germination: calculated relative to the total number of seeds (15 seeds for cucumber & bean; 20 seeds for barley & wheat) placed in each Petri dish.

[b] Percent relative germination: PRG = (MGT/MGC)×100; where MGC = mean germination in the water control; MGT = mean germination in the compost extracts.

[c] Percent relative radical length: PRRL = (MRLT/MRLC)×100; where MRLC = mean radicle length of seeds germinated in the water control; MRLT = mean radicle length of seeds germinated in the compost extracts.

[d] Zucconi's germination index: GI = (PRG × PRRL)/$10^4$.

With the multiple species bioassay there is a plant species × compost interaction. Whereas extracts of the SZ-1 or PA-1 composts produced no phytotoxic response in any of the test species, extracts of the EA-1 compost produce a mild to strong phytotoxic response in three of the test species (i.e., cucumber, wheat and barley). Again, these results most likely reflect the fact that the EA-1 extract is the most saline of the compost extracts (with an EC > 5 dS $m^{-1}$ and salt concentrations that are 1.4- to 6-times greater than that of the PA-1 extract and 6- to 11-times greater than that of the SZ-1 extract). In general, germination rates were significantly lower for cucumber than for any of the other plant species – failing to reach 50% in either the water control or compost extracts. Consequently, the results obtained with cucumber should be viewed as conservative. Even extracts from both of the peats produced mild inhibition in the barley, and the MBR peat produced mild inhibition in the cucumber.

None of the products tested (composts and peats) produced any inhibition in the beans. This is significant because it is legumes like bean that are ultimately the target for the inoculants. It is also unlikely that the amounts of carriers that are applied with the inoculant are sufficient to adversely affect seed germination.

### 3.4 Survival Studies:

#### 3.4.1 Non-sterile vs sterile carriers:

Results of the survival study using non-sterile composts and peats (Fig. 3.1) indicate that the SZ compost is unable to support rhizobial populations for an extended period of time. By day 35 of the study populations of colony forming units (CFU) were undetectable. The other two composts (EA and PA) showed slow but steady declines in rhizobial populations but sustained populations comparable to the LT commercial product up to 63 days. The LT product showed fairly low, but stable rhizobial populations throughout the study. The MBR commercial product (clay based granules), as well as the peat granules that were granulated and inoculated by us following the same protocol as the compost preparations, supported high and stable numbers of CFUs throughout the study.

The steady decline in rhizobial numbers in the compost granules does not necessarily mean that the composts are unsuitable for use as carriers, but rather that more development work needs to be done in order to determine the optimal handling procedures. Although the moisture content of the compost granules was regulated to be similar to the LT peat prills, it appears as though the moisture content was too high. Unlike the commercial products, the composts all felt sticky when handling them, and the individual granules tended to aggregate, especially in the SZ compost. Moisture content could affect the survival of the *Rhizobium*. Furthermore, indigenous populations of bacteria in the composts might be outcompeting the introduced *Rhizobium*.

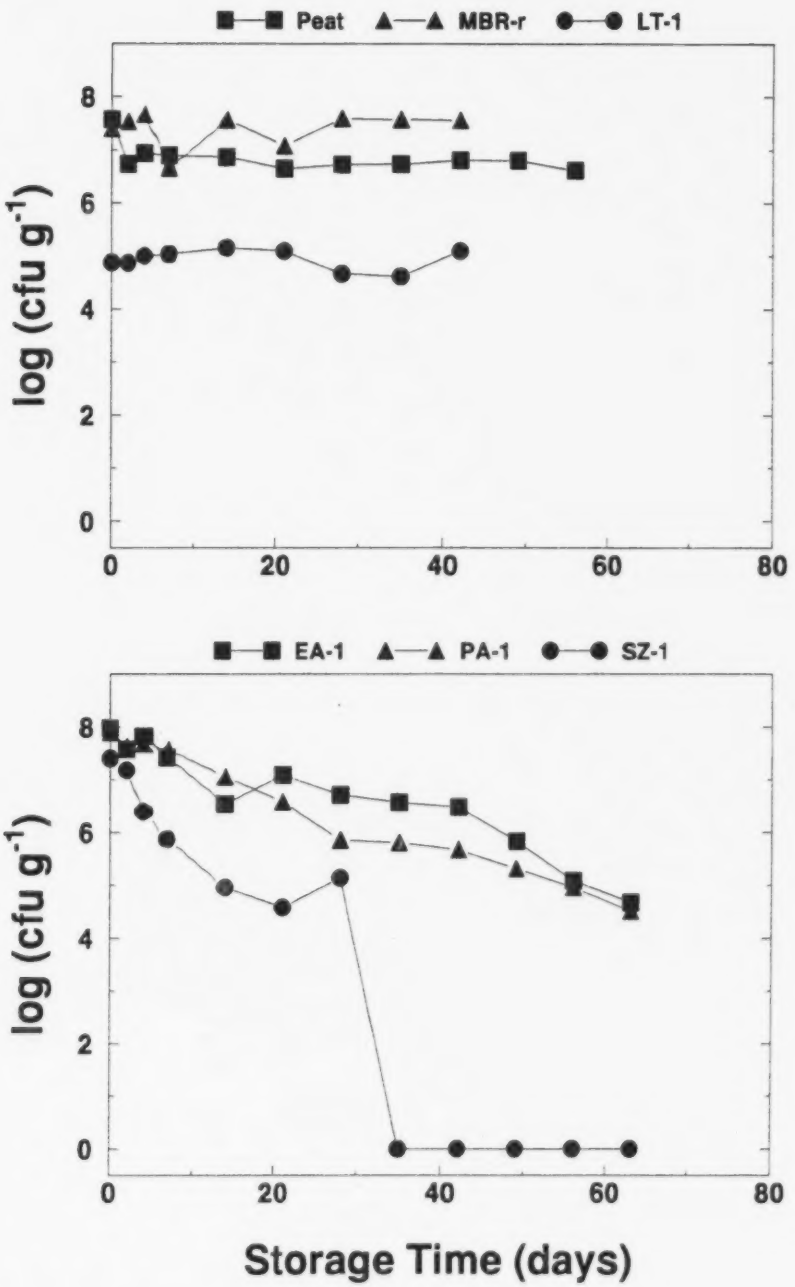


Figure 3.1. *Rhizobium* survival on non-sterile granular compost (EA-1, PA-1 and SZ-1), granular peat (Peat) and two commercial granular products (MBR-r and LT-1). The granular peat is inoculant grade peat granulated and inoculated in the same manner as the composts.

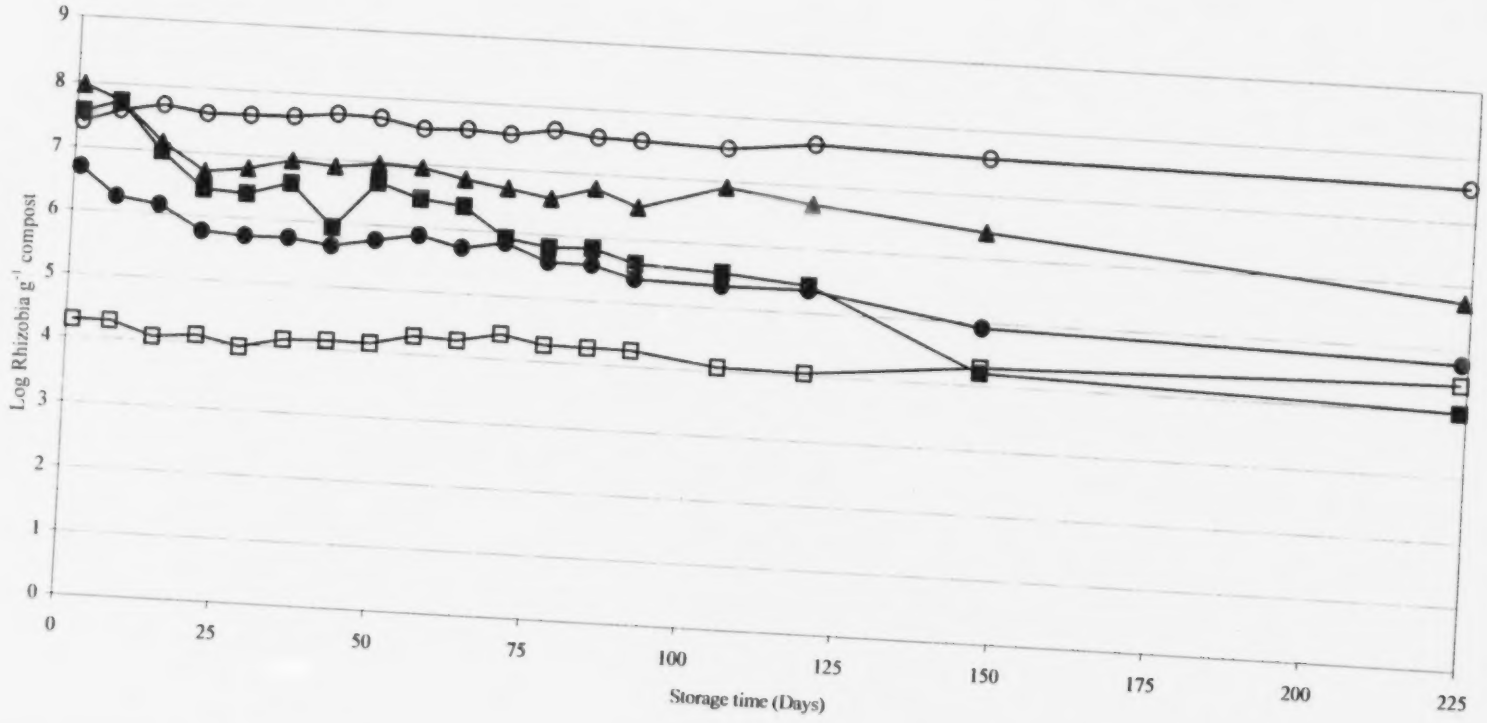


**Figure 3.2.** Survival of *R. leguminosarum* bv. *viciae* on sterile EA compost granules (EA, ●), PA compost granules (PA,■), SZ compost granules (SZ, ▲), and commercial inoculants [MBR(○) and LT(□)] stored at 4°C.

This was examined in the following experiments using sterile compost granules.

Survival of the *Rhizobium* (Fig. 3.2) was excellent on the sterilized compost granules over the 225-day duration of the experiment. 225 days (approximately 7.5 months) represents a typical storage period for inoculants. They are normally manufactured in the winter months to be used the following spring (generally a maximum of 5 months). All of the granular products supported stable populations of the introduced *Rhizobium* bacteria. Sterilization improved survivability of all of the compost-based inoculants compared to the non-sterile composts (Fig. 3.1). The reason for the better performance on sterilized products is probably the reduction in indigenous microbial populations competing with the introduced rhizobia.

Over the duration of the experiment, the compost carriers still did not perform as well as the MBR granular product and although numbers were higher on the composts than the LT control product, numbers of bacteria did decline more in the compost carriers than this control product. The LT commercial product supported the lowest, but stable numbers of rhizobia. It is quite possible that reducing the moisture (or modifying other physical attributes) in the composts could improve survival.

This study provides good first evidence that sterilized compost granules can support introduced rhizobia at levels acceptable by industry.

### *3.4.2 Nodulation Ability of Fresh and Stored Inoculants under Sterile Conditions:*

This experiment examined nodulation ability of freshly prepared and stored inoculants in sterile Leonard jars.

All of the freshly prepared inoculants were very effective at nodulating pea plants (Table 3.9). The compost-based products produced higher numbers of nodules than the MBR control product, and similar numbers to the LT control product. However, nodule number is not a good indicator of effectiveness, as a few large nodules can be as effective (or more effective) than numerous small nodules. Except for the EA inoculant, all of the inoculated products had similar nodule numbers that resulted in similar amounts of total nitrogen in the plant. These compost-based inoculants were all very similar to the MBR control in terms of total plant nitrogen, but inferior to the LT control. All of the inoculated composts also induced more N fixation (measured by total nitrogen in the plant) than their uninoculated counterpart.

Storage of the inoculated compost products reduced their effectiveness in terms of ability to nodulate and fix nitrogen in peas (Table 3.10). All of the composts induced significant nodulation in the pea roots (all were as high or higher than the controls) but the total amount of nitrogen in the plants was lower than in the previous experiment with freshly prepared inoculants (Table 3.9). All of the compost products produced more nodulation resulting in

higher total nitrogen contents than the uninoculated control. Inoculation of pea with both of the commercial control products also resulted in lower amounts of nitrogen in the pea plants, indicating some loss of viability of these rhizobia also throughout the storage period. The decrease in percent nitrogen in pea was not as extreme with the commercial products as it was with the experimental products. Clearly something occurring during the storage of the composts has reduced the effectiveness of the introduced rhizobia. One possibility is the moisture content of the granulated products. This and other possibilities should be explored further.

***Table 3.9. Ability of sterile, fresh Rhizobium-inoculated compost granules to nodulate Pisum sativum (pea) under sterile conditions.†***

| Treatment | Number of nodules (3 plants) | Nodule dry weight (mg) (3 plants) | Shoot biomass (g) | Root biomass (g) | Total nitrogen (µg) |
|---|---|---|---|---|---|
| EA | 333 $^{a}$ | 0.74 $^{b}$ | 0.79 $^{b}$ | 0.93 $^{d}$ | 0.0064 $^{bcde}$ |
| EA un‡ | 0 $^{c}$ | 0.00 $^{c}$ | 0.47 $^{b}$ | 1.58 $^{b,c}$ | 0.0013 $^{e}$ |
| PA | 312 $^{a}$ | 1.18 $^{a}$ | 0.85 $^{b}$ | 0.94 $^{d}$ | 0.0075 $^{bcd}$ |
| PA un | 0 $^{c}$ | 0.00 $^{c}$ | 0.59 $^{b}$ | 1.95 $^{a,b}$ | 0.0015 $^{de}$ |
| SZ | 310 $^{a}$ | 1.01 $^{a}$ | 0.92 $^{b}$ | 1.26 $^{c,d}$ | 0.0086 $^{b}$ |
| SZ un | 0 $^{c}$ | 0.06 $^{c}$ | 0.63 $^{b}$ | 2.21 $^{a}$ | 0.0020 $^{cde}$ |
| MBR | 85 $^{b}$ | 0.11 $^{c}$ | 1.80 $^{a}$ | 1.73 $^{b}$ | 0.0079 $^{bc}$ |
| LT | 301 $^{a}$ | 1.20 $^{a}$ | 0.98 $^{b}$ | 0.80 $^{d}$ | 0.0165 $^{a}$ |
| Control# | 0 $^{c}$ | 0.00 $^{c}$ | 0.60 $^{b}$ | 1.20 $^{c,d}$ | 0.0015 $^{de}$ |

† Means followed by the same letter within a column are not significantly different at $P<0.05$.
‡ un = uninoculated.
# No inoculant added.

***Table 3.10. Ability of 225-day-old Rhizobium-inoculated granular compost and commercial Rhizobium inoculants to nodulate Pisum sativum (pea) in sterile Leonard jars†***

| Treatment | Number of nodules (3 plants) | Nodule dry weight (mg) (3 plants) | Shoot biomass (g) | Total nitrogen (µg) |
|---|---|---|---|---|
| EA | 26 $^{c,d}$ | 0.043 $^{b}$ | 1.50 $^{c}$ | 0.011 $^{b}$ |
| PA | 112 $^{a,b}$ | 0.33 $^{a}$ | 2.16 $^{c}$ | 0.017 $^{b}$ |
| SZ | 149 $^{a}$ | 0.33 $^{a}$ | 2.52 $^{c}$ | 0.018 $^{b}$ |
| MBR | 80 $^{b,c}$ | 0.22 $^{a}$ | 5.40 $^{b}$ | 0.038 $^{a}$ |
| LT | 28 $^{c,d}$ | 0.07 $^{b}$ | 7.88 $^{a}$ | 0.050 $^{a}$ |
| Control‡ | 0 $^{d}$ | 0.00 $^{b}$ | 0.34 $^{d}$ | 0.002 $^{c}$ |

† Means followed by the same letter within a column are not significantly different at $P<0.05$.
‡ No inoculant added.

### 3.5 Growth Chamber Studies:

#### 3.5.1 Lentil

Growth chamber trials testing EA and PA granular composts for their affect on N-fixation in lentil indicate very little difference between any of the treatments at the first harvest date (Table 3.11). Except for nodule numbers and nitrogenase activity, uninoculated controls were similar to inoculated treatments. At this early harvest date it appears that soil N levels and/or initial seed N values were sufficient to support good growth of the lentil plant.

The PA non-sterile granules supported the highest nitrogenase activity per mass unit of nodule. This indicates that the few (and/or small) nodules that were present were very active. These plants were the smallest of all of the treatment plants in terms of biomass, indicating that nitrogen fixation was not sufficient to support optimal growth. Overall there is little difference among the inoculant treatment plants in terms of growth, and nitrogenase activity, suggesting that all of the inoculant products performed in a similar manner.

Even at the final harvest there is no difference in the amount of shoot biomass production among the different inoculant treatments (Table 3.11). However, nitrogen derived from atmosphere (Ndfa) indicated that all of the inoculated compost products were fixing higher amounts of nitrogen compared to uninoculated controls. In general, the granular products, including the commercial control product (MBR-G-S) were less effective than the seed applied products. Other reports indicate that granular formulations are more effective than seed applied formulations (Bezdicek et al. 1978, Muldoon et al. 1980) in field situations. Granular products are thought to be more effective at introducing rhizobia into deeper moist layers in the soil than seed applied products, resulting in more protection to the bacteria. However, in a growth chamber situation where pots are watered regularly, this is not an issue. Granular products rely on roots of the legume growing to intercept the placement of the granule. With seed applied products, there is little possibility of the roots not becoming infected with the bacteria applied to the seed coat. Furthermore, granular products may only be more effective that seed applied products in situations where they are applied to "virgin soils" that have never grown the pulse crop in question and hence never received an external inoculant application (Al. Slinkard, person. commun).

Generally, the sterilized products were more effective at inducing nitrogen fixation than the non-sterile products, especially the powdered products (Table 3.11). Reducing the native populations inhabiting the composts appears to increase the effectiveness of the introduced rhizobia. All of the Ndfa values are relatively low, indicating that the stain of bacteria (supplied by MBR) is perhaps not ideal for lentil. Nitrogen derived from atmosphere can be as high as 80% in many pulse crops. Alternatively, light levels in the growth chamber may not have been sufficient for optimal growth. All other chamber conditions were controlled to

near optimum levels.

### 3.5.2 Pea

Results for the pea experiment are similar to the lentil except that there is more variability especially in the mid-season harvest measurements (Table 3.12). Two of the compost-based inoculants showed complete failure (no nodulation, low biomass values, and low Ndfa) but all of the remaining compost-based inoculants were similar to or superior to the MBR commercial control. Surprisingly, both of the failed compost-base inoculants were sterile forms, one is a powder based formulation (EA-P-S) and the other a granule (PA-G-S). Clearly some factors that we have not identified are affecting survival in soil conditions. Once again, it might be indigenous bacterial populations in the soil environment that are outcompeting the introduced bacteria, but why this occurred with only two of the products is unclear. It is more likely that something happened during the application of the rhizobial cultures to the compost carriers that compromised the survival of the bacteria.

All of the other inoculated compost carriers were equally successful at inducing symbiotic nitrogen fixation in pea. The uninoculated carriers were associated with low levels of nodulation and low nitrogen fixation levels. However, the observation that nodulation still occurred along with low levels of nitrogen fixation in these uninoculated controls indicates that indigenous rhizobia were present in the soil.

In this experiment, the non-sterile granular products (EA-G-NS and PA-G-NS) supported the highest nitrogen fixation rates. This is despite the observation in the storage experiments that sterile products were able to support higher populations of rhizobia over long periods of time compared to non-sterile products. In this growth chamber study, freshly prepared inoculant products were used. With fresh products it appears that sterilization of the carrier is not an issue.

Results from the growth chamber trials are not conclusive. However, they do lend support for composts being used as carriers for rhizobial inoculants. It is clear that more research addressing physical properties, like moisture content, as well as issues surrounding storage and inoculation protocols is necessary.

***Table 3.11 Productivity and nitrogenase ($N_2$-fixation) status of lentil inoculated with Rhizobia on various compost or commercial carriers Plants were grown in a growth chamber and harvested at mid-flowering and late flowering. Values are means of 3 replicates.***

| | Mid-season harvest | | | | | | Final harvest | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatment[1] | Shoot Weight (g) | Root Weight (g) | Total Weight (mg) | Nodule Weight (mg) | Nodule number | Nitrogenase (ppm/h/mg nodule) | Shoot Weight (g) | Shoot N (%) | Ndfa (%) |
| Control[2] | 0.74a | 0.22a | 0.966ab | 1.4a | 2.7bc | 4.9a | 2.61a | 1.6 | 5.5 |
| MBR-P-S | 0.73a | 0.24a | 0.973ab | 4.1a | 23.3abc | 1.4a | 2.55a | 2.0 | 36.2 |
| MBR-G-S | 0.77a | 0.29a | 1.063a | 2.6a | 17.3abc | 2.3a | 2.49a | 2.0 | 20.2 |
| EA-P-NS | 0.77a | 0.20a | 0.972ab | 7.0a | 35.7a | 1.9a | 3.14a | 2.0 | 15.6 |
| EA-P-S | 0.76a | 0.22a | 0.978ab | 3.7a | 32.3a | 1.1a | 2.79a | 2.1 | 42.8 |
| EA-G-NS | 0.63ab | 0.27a | 0.896ab | 6.4a | 34.3a | 2.1a | 2.45a | 2.2 | 34.9 |
| EA-G-S | 0.56ab | 0.47a | 1.030a | 4.1a | 23.7abc | 1.3a | 2.54a | 2.1 | 21.3 |
| EA-G-NS-U | 0.60acb | 0.19a | 0.793ab | 1.9a | 10abc | 2.1a | 2.92a | 1.8 | 7.7 |
| EA-G-S-U | 0.72a | 0.38a | 1.100a | 5.5a | 24.7abc | 1.5a | 2.73a | 2.1 | 5.1 |
| PA-P-NS | 0.72a | 0.32a | 1.040a | 3.0a | 19.3abc | 2.3a | 2.30a | 2.0 | 19.1 |
| PA-P-S | 0.69a | 0.26a | 0.956a b | 5.0a | 25.7abc | 1.2a | 2.78a | 2.0 | 40.9 |
| PA-G-NS | 0.45b | 0.17a | 0.616b | 0.9a | 3.7bc | 5.2a | 2.34a | 2.3 | 19.7 |
| PA-G-S | 0.71a | 0.34a | 1.050a | 7.3a | 27.3ab | 1.6a | 2.89a | 2.1 | 13.7 |
| PA-G-NS-U | 0.60ab | 0.30a | 0.900ab | 1.1a | 3bc | 3.1a | 2.69a | 1.9 | 5.1 |
| PA-G-S-U | 0.72a | 0.39a | 1.113a | 3.9a | 14.7abc | 2.4a | 2.93a | 2.1 | 5.5 |

[1]Treatments are coded according to: Product-Formulation-Sterility status-Inoculation status according to the following codes:

Product: MBR=commercial inoculant manufactured by MicroBioRhizogen, EA=EcoAg Initiatives compost; PA= Prince Albert Penitentiary compost

Formulation: P=powder; G=granular

Sterility status: S=sterilized by UV irradiation; NS= not sterilized.

Inoculation status: U=uninoculated; all others are inoculated

[2] Controls are uninoculated with no product added.

Numbers in a column followed by the same letter are not significantly different at $\alpha$=0.10 according to the Student-Newman Keuls test.

***Table 3.12 Productivity and nitrogenase ($N_2$-fixation) status of pea inoculated with Rhizobia on various compost or commercial carriers Plants were grown in a growth chamber and harvested at mid-flowering and late flowering. Values are means of 3 replicates.***

| | Mid-season harvest | | | | Final harvest | | |
|---|---|---|---|---|---|---|---|
| Treatment[1] | Shoot Weight (g) | Nodule Weight (mg) | Nodule number | Nitrogenase (ppm/h/mg nodule) | Shoot Weight (g) | Shoot N (%) | Ndfa (%) |
| Control[2] | 0.54a | 0b | 0a | 0c | 2.13 | 1.3 | 17.3 |
| MBR-P-S | 0.73a | 24.9a | 10.5a | 0.89ab | 2.64 | 2.0 | 52.8 |
| MBR-G-S | 0.91a | 27.5a | 32.5a | 0.37b | 2.68 | 1.6 | 63.1 |
| EA-P-NS | 1.12a | 39.0a | 42.0a | 0.43b | 2.34 | 2.0 | 51.0 |
| EA-P-S | 0.44a | 0b | 0a | 0c | 1.28 | 1.5 | 7.7 |
| EA-G-NS | 1.10a | 41.9a | 59.0a | 0.61ab | 1.67 | 1.5 | 65.4 |
| EA-G-S | 0.92a | 26.1a | 27.0a | 0.64ab | 2.07 | 1.7 | 44.9 |
| EA-G-NS-U | 1.09a | 27.9a | 22.0a | 0.21b | 2.64 | 1.3 | 11.2 |
| EA-G-S-U | 0.82a | 10.2ab | 3.0a | 1.22a | 2.30 | 1.5 | 15.6 |
| PA-P-NS | 0.88a | 26.7a | 48.0a | 1.37a | 2.56 | 1.6 | 50.2 |
| PA-P-S | 1.02a | 15.9ab | 6.0a | 1.10a | 2.20 | 2.1 | 50.3 |
| PA-G-NS | 1.01a | 74.0a | 94.0a | 0.22b | 3.19 | 1.7 | 61.6 |
| PA-G-S | 0.40a | 0b | 0a | 0c | 2.15 | 2.2 | 13.1 |
| PA-G-NS-U | 0.57a | 4.34ab | 11.0a | 0.93ab | 1.93 | 1.0 | 12.0 |
| PA-G-S-U | 0.59a | 3.35ab | 25.0a | 0.91ab | 1.94 | 1.2 | 16.5 |

[1]Treatments are coded according to: Product-Formulation-Sterility status-Inoculation status according to the following codes:

Product: MBR=commercial inoculant manufactured by MicroBioRhizogen, EA=EcoAg Initiatives compost; PA= Prince Albert Penitentiary compost

Formulation: P=powder; G=granular

Sterility status: S=sterilized by UV irradiation; NS= not sterilized.

Inoculation status: U=uninoculated; all others are inoculated

[2] Controls are uninoculated with no product added.

Numbers in a column followed by the same letter are not significantly different at $\alpha$=0.10 according to the Student-Newman Keuls test.

### 3.6 Field Studies:

Both of the field seasons in 2001 and 2002 were plagued by severe drought. In 2002, the site at Conquest was lost due to a combination of the drought and grasshoppers. Although results are presented here they should be viewed with caution as they are not representative of a field season receiving normal or even near normal moisture.

Drought affects not only plant growth, but survival of microorganisms including introduced *Rhizobium,* as well as the development of nodules and nitrogen fixation directly. The formation of nodules for nitrogen fixation requires energy that is supplied by the plant, using some of the plant reserves (photosynthates) that might have been used for seed development. Under very dry conditions, where water is more limiting than nitrogen, an advantage to nodulation and active nitrogen fixation might not be observed.

**2001:**

There was a lot of variability both within a treatment at a site and between sites for all of the parameters measured mid-season, presumably attributable to the drought (Table 3.13 and 3.14). Both pea and lentil plants grown at the Clavet site had the smallest plants (shoot biomass) but the largest mass of nodules. There is extreme variability in the nodule masses within a treatment. Plants inoculated with the commercial products (MBR peat and MBR granular) tended to be the largest with the largest nodule mass, but in many cases the compost products are comparable. None of the composts was visibly superior to the others at this stage.

Because of the severe drought experienced over much of the province this year, final yield samples are only representative of drought year (Table 3.15) and must be interpreted cautiously. The pea plots were considerably more productive than the lentil plots. In most cases the inoculant treatments (regardless of formulation) were higher yielding than the uninoculated controls, indicating that some biological N fixation probably was occurring despite the drought conditions. This was supported by the seed N data. At all sites, plants grown in the uninoculated control plots had lower percentages of nitrogen in the seed. However, these plots still tended to be fairly productive relative to the inoculated treatment plots and probably indicate a relatively high level of indigenous Rhizobium in the soil. All of the sites are in pea or lentil production areas and have pulses appearing regularly in rotation. None of the sites have a pulse in the year preceding the experimental year. As was the case at the mid-season harvest, the MBR peat plots tended to be the highest yielding. None of the compost treatments was clearly superior or inferior to the others.

While these results are not representative of a year with near normal moisture levels, they do indicate that the compost inoculants are effective in a drought year.

***Table 3.13: Biomass and nitrogenase activity for mid-season (July 2001) sampling of field pea plots.***

| Site | Treatment | Shoot Weight (g/5 plants) | Root Weight (g/5 plants) | Nodule Weight (mg/plant) | Nitrogenase (ppm/h/mg nodule) |
|---|---|---|---|---|---|
| Clavet | Control | 8.40 | 0.69 | 31.5 | 1.36 |
| | MBR peat | 11.32 | 0.82 | 129.3 | 1.14 |
| | MBR granular | 12.09 | 0.75 | 80.9 | 1.47 |
| | EA powder | 8.77 | 0.89 | 52.4 | 1.49 |
| | EA granular | 7.91 | 0.61 | 46.1 | 1.47 |
| | PA powder | 9.29 | 0.67 | 55.8 | 1.32 |
| | PA granular | 9.37 | 0.64 | 67.5 | 1.43 |
| | SZ powder | 8.25 | 0.55 | 22.0 | 1.57 |
| | SZ granular | 9.81 | 0.68 | 67.7 | 1.39 |
| $lsd_{0.10}$ | | 1.53 | 0.24 | 44.7 | 0.45 |
| Rosthern | Control | 22.40 | 0.70 | 5.1 | 1.63 |
| | MBR peat | 21.76 | 0.53 | 7.3 | 2.07 |
| | MBR granular | 24.36 | 0.85 | 21.7 | 1.07 |
| | EA powder | 25.67 | 0.70 | 11.7 | 2.47 |
| | EA granular | 23.59 | 0.72 | 9.6 | 2.66 |
| | PA powder | 24.03 | 1.13 | 21.8 | 0.81 |
| | PA granular | 23.55 | 0.69 | 7.6 | 0.93 |
| | SZ powder | 27.10 | 0.68 | 9.4 | 0.83 |
| | SZ granular | 21.41 | 0.62 | 3.5 | 1.57 |
| $lsd_{0.10}$ | | 5.64 | 0.45 | 17.2 | 0.98 |

***Table 3.14: Biomass and nitrogenase activity for mid-season (July 2001) sampling of field lentil plots.***

| Site | Treatment | Shoot Weight (g/5 plants) | Root Weight (g/5 plants) | Nodule Weight (mg/plant) | Nitrogenase (ppm/h/mg nodule) |
|---|---|---|---|---|---|
| Clavet | Control | 4.68 | 0.56 | 1.98 | 1.38 |
| | MBR peat | 8.08 | 0.59 | 22.83 | 0.26 |
| | MBR granular | 4.25 | 0.47 | 3.30 | 2.08 |
| | EA powder | 4.14 | 0.39 | 2.02 | 3.95 |
| | EA granular | 5.95 | 0.53 | 8.67 | 0.81 |
| | PA powder | 4.42 | 0.43 | 2.56 | 3.62 |
| | PA granular | 6.20 | 0.58 | 13.14 | 0.84 |
| | SZ powder | 4.88 | 0.54 | 3.49 | 2.39 |
| | SZ granular | 5.26 | 0.46 | 8.08 | 1.36 |
| $lsd_{0.10}$ | | 2.83 | 0.43 | 10.21 | 1.01 |
| Conquest | Control | 13.67 | 0.35 | 4.61 | 1.36 |
| | MBR peat | 15.91 | 0.37 | 3.57 | 1.57 |
| | MBR granular | 16.26 | 0.45 | 3.51 | 1.83 |
| | EA powder | 14.05 | 0.32 | 1.90 | 4.77 |
| | EA granular | 15.42 | 0.43 | 5.75 | 0.71 |
| | PA powder | 14.89 | 0.25 | 2.88 | 1.88 |
| | PA granular | 16.32 | 0.29 | 5.71 | 1.17 |
| | SZ powder | 16.33 | 0.40 | 3.52 | 1.42 |
| | SZ granular | 16.95 | 0.39 | 2.88 | 1.78 |
| $lsd_{0.10}$ | | 2.12 | 0.21 | 3.32 | 2.54 |

***Table 3.15. Seed yields for field pea and lentil 2001 field plots treated with different inoculant formulations.***

| Lentil Sites | | | Pea Sites | | |
|---|---|---|---|---|---|
| Treatment | Yield (kg/ha) | Seed N (%) | Treatment | Yield (kg/ha) | Seed N (%) |
| *Clavet* | | | *Clavet* | | |
| Control | 183 | 1.7 | Control | 539 | 2.4 |
| MBR peat | 324 | 2.2 | MBR peat | 714 | 2.6 |
| MBR gran | 157 | 2.0 | MBR gran | 616 | 2.7 |
| EA pdr | 214 | 2.1 | EA pdr | 597 | 2.5 |
| EA gran | 245 | 2.1 | EA gran | 678 | 2.7 |
| PA pdr | 230 | 2.0 | PA pdr | 604 | 2.7 |
| PA gran | 281 | 1.8 | PA gran | 557 | 2.6 |
| SZ pdr | 197 | 1.9 | SZ pdr | 592 | 2.6 |
| SZ gran | 230 | 2.0 | SZ gran | 614 | 2.7 |
| $lsd_{0.10}$ | 174 | 0.5 | | 233 | 0.6 |
| *Conquest* | | | *Rosthern* | | |
| Control | 207 | 2.3 | Control | 631 | 2.3 |
| MBR peat | 403 | 2.7 | MBR peat | 833 | 2.5 |
| MBR gran | 354 | 2.7 | MBR gran | 814 | 2.6 |
| EA pdr | 413 | 2.5 | EA pdr | 945 | 2.5 |
| EA gran | 310 | 2.6 | EA gran | 999 | 2.6 |
| PA pdr | 212 | 2.5 | PA pdr | 743 | 2.4 |
| PA gran | 313 | 2.5 | PA gran | 872 | 2.4 |
| SZ pdr | 250 | 2.6 | SZ pdr | 738 | 2.4 |
| SZ gran | 292 | 2.7 | SZ gran | 618 | 2.5 |
| $lsd_{0.10}$ | 221 | 0.6 | | 313 | 0.5 |

**2002:**

Once again the drought during the growing season of 2002 greatly inhibited plant growth at all of the sites. In addition to the drought, grasshoppers wiped out the site at Conquest early in the season. We were able to harvest the plants at mid-flowering at Conquest, but lost the site shortly after this. Ecobait (a chaff treated with pesticide) was applied to the buffer strips around this site three times early in the season but this only delayed grasshoppers reaching these plots.

The mid-season harvest for both the pea and lentil sites indicated no differences between the inoculant formulations (Tables 3.16 and 3.17). However, the plants in the control plots at all of the sites also had significant nodulation as well, indicating native or over-wintering rhizobia in the soils. Sites were selected on the basis of having relatively low nitrogen

contents, and rotation histories where-by the legume was not seeded into another legume stubble. However, none of the sites were virgin sites, in that they had never had lentil or pea grown on them before. It appears that at least in the early season harvest that indigenous rhizobia infected the plants. Furthermore, because of the drought water was much more limiting to plant growth than was nitrogen. Any effect of an introduced, superior strain of rhizobia was overshadowed by the water limitation.

At final harvest (Table 3.18 and 3.19) there is some indication that the inoculants were effective at the Clavet site. Inoculated plants were higher yielding than controls, but this only occurs at the Clavet site. All of the nitrogen content numbers indicate that regardless of the treatment the plants have sufficient N, once again indicating that nitrogen is not limiting to plant growth, water is. At the Rosthern site, the MBR peat based inoculant was superior to the other inoculants. Total yields and seed yields were higher in plants from this treatment. However, the extremely low harvest indices at this site illustrate just how poor this site performed. In addition, the high nitrogen percentages for total plant and seed further illustrates the severe stunting of these plants. Any nitrogen that was taken up by the plants or fixed by the plants was concentrated in the very small plants. At all of the sites it appears that water was more limiting to plant growth and seed development than was nitrogen.

***Table 3.16: Productivity and nitrogenase activity ($N_2$ fixation) for pea inoculated with different compost or commercial inoculant formulations harvested at mid-flowering at two field sites in 2002.***

| Treatment[1] | Shoot Weight (mg) | Root Weight (mg) | Nodule Weight (mg) | Nitrogenase (ppm/h/mg nodule) | Nodule number |
|---|---|---|---|---|---|
| | | | ***Clavet*** | | |
| Control[2] | 7.32 | 570 | 10 | 0.178 | 203 |
| MBR-P-S | 8.72 | 605 | 65 | 0.353 | 213 |
| MBR-G-S | 4.29 | 425 | 65 | 0.701 | 216 |
| EA-P-NS | 8.58 | 501 | 30 | 0.309 | 155 |
| EA-P-S | 7.19 | 505 | 25 | 0.668 | 128 |
| EA-G-NS | 8.27 | 572 | 63 | 0.536 | 170 |
| EA-G-S | 5.76 | 468 | 70 | 2.486 | 190 |
| PA-P-NS | 7.63 | 621 | 12 | 0.480 | 92 |
| PA-P-S | 7.18 | 480 | 63 | 0.533 | 195 |
| PA-G-NS | 5.51 | 528 | 45 | 0.412 | 206 |
| PA-G-S | 7.99 | 498 | 50 | 0.506 | 135 |
| $lsd_{0.10}$ | 3.12 | 134 | 64 | - | 131 |
| | | | ***Rosthern*** | | |
| Control[2] | 5.99 | 614 | 39 | 0.032 | 69 |
| MBR-P-S | 8.68 | 382 | 52 | 0.104 | 78 |
| MBR-G-S | 5.54 | 456 | 64 | 0.049 | 88 |
| EA-P-NS | 6.28 | 473 | 45 | 0.057 | 72 |
| EA-P-S | 6.43 | 466 | 51 | 0.100 | 86 |
| EA-G-NS | 5.5 | 442 | 96 | 0.433 | 75 |
| EA-G-S | 6.99 | 441 | 68 | 0.172 | 77 |
| PA-P-NS | 11.84 | 548 | 88 | 0.418 | 43 |
| PA-P-S | 7.88 | 468 | 48 | 0.222 | 48 |
| PA-G-NS | 7.65 | 510 | 58 | 0.734 | 80 |
| PA-G-S | 5.62 | 494 | 8 | 0.440 | 69 |
| $lsd_{0.10}$ | 5.19 | 142 | 7 | - | 57 |

[1]Treatments are coded according to: Product-Formulation-Sterility status according to the following codes:

Product: MBR=commercial inoculant manufactured by MicroBioRhizogen, EA=EcoAg Initiatives compost; PA= Prince Albert Penitentiary compost

Formulation: P=powder; G=granular

Sterility status: S=sterilized by UV irradiation; NS=not sterilized.

[2] Controls are uninoculated with no product added.

***Table 3.17 Productivity and nitrogenase activity ($N_2$ fixation) for lentil inoculated with different compost or commercial inoculant formulations harvested at mid-flowering at two field sites in 2002.***

| Treatment[1] | Shoot Weight (mg) | Root Weight (mg) | Nodule Weight (mg) | Nitrogenase (ppm/h/mg nodule) | Nodule number |
|---|---|---|---|---|---|
| | | ***Dinsmore*** | | | |
| Control[2] | 2.86 | 325 | 5 | 0.327 | 26 |
| MBR-P-I-S | 3.26 | 362 | 7 | 0.639 | 29 |
| MBR-G-I-S | 2.31 | 317 | 4 | 2.099 | 20 |
| EA-P-I-NS | 3.33 | 289 | 3 | 2.815 | 14 |
| EA-P-I-S | 2.89 | 290 | 5 | 1.109 | 24 |
| EA-G-I-NS | 2.70 | 310 | 6 | 1.107 | 19 |
| EA-G-I-S | 3.24 | 380 | 7 | 1.118 | 30 |
| PA-P-I-NS | 3.47 | 307 | 5 | 1.215 | 18 |
| PA-P-I-S | 2.34 | 280 | 5 | 0.959 | 19 |
| PA-G-I-NS | 3.58 | 354 | 5 | 1.211 | 21 |
| PA-G-I-S | 1.59 | 228 | 6 | 0.918 | 26 |
| $lsd_{0.10}$ | 1.78 | 118 | 3 | | 15 |
| | | ***Conquest*** | | | |
| Control[2] | 0.83 | 213 | 23 | 0.275 | 52 |
| MBR-P-I-S | 1.27 | 341 | 22 | 1.419 | 45 |
| MBR-G-I-S | 1.22 | 287 | 25 | 0.504 | 41 |
| EA-P-I-NS | 0.78 | 267 | 15 | 0.631 | 38 |
| EA-P-I-S | 0.96 | 212 | 23 | 0.473 | 46 |
| EA-G-I-NS | 1.31 | 251 | 22 | 0.404 | 45 |
| EA-G-I-S | 1.13 | 241 | 29 | 0.153 | 67 |
| PA-P-I-NS | 1.01 | 218 | 18 | 0.396 | 43 |
| PA-P-I-S | 1.02 | 264 | 15 | 0.574 | 36 |
| PA-G-I-NS | 1.25 | 307 | 21 | 0.277 | 52 |
| PA-G-I-S | 0.94 | 286 | 20 | 0.329 | 33 |
| $lsd_{0.10}$ | 0.41 | 109 | 10 | - | 23 |

[1]Treatments are coded according to: Product-Formulation-Sterility status according to the following codes:
Product: MBR=commercial inoculant manufactured by MicroBioRhizogen, EA=EcoAg Initiatives compost; PA= Prince Albert Penitentiary compost
Formulation: P=powder; G=granular
Sterility status: S=sterilized by UV irradiation; NS=not sterilized.
[2] Controls are uninoculated with no product added.

***Table 3.18 Final yields and nitrogen contents of pea inoculated with different compost or commercial inoculant formulations at two field sites in 2002.***

| Treatment[1] | Total Yield (kg/ha) | Seed Yield | Harvest Index | Total Plant N (%) | Seed N (%) |
|---|---|---|---|---|---|
| | | ***Clavet*** | | | |
| Control[2] | 950 | 699 | 0.36 | 3.15 | 3.02 |
| MBR-P-I-S | 1704 | 608 | 0.36 | 3.12 | 2.93 |
| MBR-G-I-S | 1925 | 664 | 0.34 | 2.65 | 3.16 |
| EA-P-I-NS | 1784 | 598 | 0.34 | 2.67 | 3.08 |
| EA-P-I-S | 1733 | 601 | 0.35 | 3.07 | 3.18 |
| EA-G-I-NS | 1823 | 673 | 0.36 | 2.65 | 2.91 |
| EA-G-I-S | 1889 | 727 | 0.37 | 3.22 | 3.10 |
| PA-P-I-NS | 2060 | 749 | 0.36 | 3.92 | 3.30 |
| PA-P-I-S | 1813 | 655 | 0.36 | 2.89 | 3.03 |
| PA-G-I-NS | 1931 | 683 | 0.35 | 2.65 | 3.03 |
| PA-G-I-S | 2204 | 768 | 0.34 | 3.43 | 3.10 |
| $lsd_{0.10}$ | 438 | 222 | 0.05 | 0.74 | 0.41 |
| | | ***Rosthern*** | | | |
| Control[2] | 643 | 65 | 0.08 | 3.21 | 4.18 |
| MBR-P-I-S | 1099 | 121 | 0.10 | 3.55 | 4.24 |
| MBR-G-I-S | 696 | 78 | 0.10 | 2.99 | 4.56 |
| EA-P-I-NS | 909 | 99 | 0.09 | 3.30 | 4.42 |
| EA-P-I-S | 853 | 104 | 0.11 | 3.17 | 4.21 |
| EA-G-I-NS | 635 | 69 | 0.08 | 3.07 | 4.45 |
| EA-G-I-S | 928 | 103 | 0.10 | 3.55 | 4.12 |
| PA-P-I-NS | 829 | 49 | 0.06 | 2.93 | 4.46 |
| PA-P-I-S | 681 | 77 | 0.12 | 2.79 | 4.28 |
| PA-G-I-NS | 603 | 76 | 0.13 | 3.19 | 4.45 |
| PA-G-I-S | 746 | 84 | 0.11 | 3.03 | 4.28 |
| $lsd_{0.10}$ | 471 | 89 | 0.08 | 0.62 | 0.49 |

[1]Treatments are coded according to: Product-Formulation-Sterility status according to the following codes:

Product: MBR=commercial inoculant manufactured by MicroBioRhizogen, EA=EcoAg Initiatives compost; PA= Prince Albert Penitentiary compost

Formulation: P=powder; G=granular

Sterility status: S=sterilized by UV irradiation; NS=not sterilized.

[2] Controls are uninoculated with no product added.

***Table 3.19: Final yields and nitrogen contents of lentil inoculated with different compost or commercial inoculant formulations at one field site in 2002.***

| Treatment[1] | Total Yield | Seed Yield | Harvest Index | Total Plant N (%) | Seed N (%) |
|---|---|---|---|---|---|
| | | | ***Dinsmore*** | | |
| Control[2] | 1253 | 531 | 0.42 | 3.40 | 3.62 |
| MBR-P-I-S | 1348 | 504 | 0.36 | 4.01 | 3.64 |
| MBR-G-I-S | 1410 | 565 | 0.39 | 3.34 | 3.71 |
| EA-P-I-NS | 1305 | 507 | 0.38 | 3.56 | 3.69 |
| EA-P-I-S | 1384 | 562 | 0.40 | 3.89 | 3.71 |
| EA-G-I-NS | 1364 | 575 | 0.41 | 3.95 | 3.60 |
| EA-G-I-S | 1649 | 635 | 0.39 | 3.60 | 3.49 |
| PA-P-I-NS | 1621 | 659 | 0.41 | 4.03 | 3.70 |
| PA-P-I-S | 1373 | 610 | 0.43 | 3.94 | 3.62 |
| PA-G-I-NS | 1294 | 510 | 0.39 | 3.71 | 3.49 |
| PA-G-I-S | 1581 | 583 | 0.36 | 3.25 | 3.61 |
| $lsd_{0.10}$ | 331 | 205 | 0.07 | 0.59 | 0.32 |

[1]Treatments are coded according to: Product-Formulation-Sterility status according to the following codes:

Product: MBR=commercial inoculant manufactured by MicroBioRhizogen, EA=EcoAg Initiatives compost; PA= Prince Albert Penitentiary compost

Formulation: P=powder; G=granular

Sterility status: S=sterilized by UV irradiation; NS=not sterilized.

[2] Controls are uninoculated with no product added.

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None to report.

**(g) Project developed materials:**

Farrell, R.E. 2002. Composting *In*: Best Management Practices for Agriculture. Video produced by Soil conservation Council of Canada, Saskatoon, SK.

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